Volume XX SECTION B

JOURNAL

OF

THE MADRAS UNIVERSITY

ORIGINAL CONTRIBUTIONS IN MATHEMATICS, PHYSICAL AND BIOLOGICAL SCIENCES.

PUBLISHED BY THE UNIVERSITY
MADRAS
1950

NOTICE

TO CONTRIBUTORS AND OTHERS

Citation shall be : *Jour. Madras Univ., Sect.* B, Vol.

Contributions, remittances, books for review, exchanges, and correspondence regarding all matters may be addressed to :

UNIVERSITY BUILDINGS
MADRAS

DR. C. P. GNANAMUTHU
Editor

Volume XX SECTION B

JOURNAL

OF

THE MADRAS UNIVERSITY

PUBLISHED BY THE UNIVERSITY
MADRAS
1950

TABLE OF CONTENTS

SOFT ROT OF RADISH (*RAPHANUS SATIVUS* L.)

BY

G. S. VERMA, M.Sc., PH.D.
University of Lucknow

INTRODUCTION

In August 1943, Dr. S. N. Das Gupta observed some rotting radish roots (tap-root of *Raphanus sativus* L.) emanating offensive smell. He suggested to the author to isolate the organisms responsible for producing the damage. Subsequently various fields were visited on Barabanki Road, Lucknow and collected. In the fields visited the occurrence of the disease was confined to secluded areas where poor drainage was keeping the soil in a soggy condition.

A similar search for the disease in winter crop of radish showed its occurrence in very few cases and those also were in the early part of November.

By appropriate methods described elsewhere, a fungus was isolated which has been provisionally identified as *Pythium aphanidermatum*. The fungus apparently enters the plant at or near the soil level and grows into the protruding tap-root, at the same time invading the leaf-petioles.

SYMPTOMS OF THE DISEASE

Newly invaded tissues exhibit at first water-soaked appearance dirty yellow in colour, quite distinct from the healthy white region (Plate 1, Fig. 1), but as the decay progresses, the infected tissues gradually change into yellowish brown colour, the cells separate out altogether into a shapeless mass showing dark brown colour which soon crumbles down. This is the final stage of disintegration of the radish tissue under the attack of the parasite. In the diseased tissue the older infected region is brown and in the periphery where the fungus is invading the healthy tissues, the colour is usually dull yellow.

The contents of the radish cells also undergo progressive deterioration due to the parasite. The cytoplasm which in healthy

condition is granular and contains starch and other characteristic food material gradually shrinks away from the cell wall under the influence of the fungus. The cells lose the granular contents and the colour is also changed.

The fungus progresses through the cortical region and is intercellular, although in some cases hyphae have been found to penetrate inside the cells showing the intracellular nature. The fungal hpyhae advance through the cortical cells and destroy them completely but never attack the vascular elements which therefore are left intact. In a very badly diseased radish therefore the cortical tissues disintegrate and crumble down leaving the shrivelled strands of vascular elements of the root. The entire diseased area becomes extremely soft and pulpy showing a moist appearance. A peculiar offensive smell is characteristic of the soft rot of radish.

Simultaneously with the advance of the fungus into the taproot and consequent infection reaching the leaf base, the fungus is found to attack the cells through the cortical tissues and pass on to the lamina. The tissues in the region of the leaf base disintegrate due to the destructive influence of the fungus in the same manner as in the radish root. With the advance of the disease the healthy green colour of the leaf changes into yellow and finally the entire leaf droops down. The green appearance of the leaves is transformed into a dull green shade and the invaded area appears water soaked, getting softer and pulpy.

At the very early stage of the disease as the fungal hyphae penetrate the cortical region, the middle lamellae of the cells get dissolved due to the action of the fungus and separate out from each other.

Isolations

The diseased tissue on examination under the microscope revealed the presence of unseptate hyphae in great abundance but no sexual bodies were observed. For the isolation of the pathogen, two methods were employed viz., (1) Naturally infected radish roots were placed in sterile moist chambers and the pathogen was allowed to grow for two or three days when copious mycelium appeared on the surface of the moist decayed tissue. Inoculum from this mycelial growth was transferred to the standard synthetic medium and allowed to grow.

(2) The freshly infected tissue was surface sterilised with (1 : 1000) mercuric chloride and the diseased part was exposed by

means of a sterilised scalpel. The inoculations were taken from the region showing most recent infection and placed on agar and Brown's standard medium. After 48 hours, a dense fluffy white mycelial growth was observed. Two different kinds of bacteria were also found associated with the fungus which are described elsewhere.

A very large number of isolations were made by these two methods. On examination all the cultures were found to belong to one species of fungus — *Pythium*. There was no other fungus associated with *Pythium* except the two forms of bacteria.

The fungus and the bacteria were next obtained in pure cultures by the following methods :

To 10 c.c. of the oat-agar medium, 3 drops of 25% lactic acid were added and the contaminated fungus was inoculated on the medium. The fungus grew out on this acidified medium leaving the bacteria confined to the centre of the culture. Portions of hyphae from the bacteria-free advancing region were then transferred to agar slants.

The bacteria were separated by the dilution method in peptone agar medium. Two different kinds of colonies were isolated and separately cultured.

Monohyphal cultures were made from a number of purified cultures by the following method : A sterilised slide over which a drop of nutrient medium was spread out was inoculated with uncontaminated fungal mycelium and placed in a moist chamber. When only a few hyphae had grown out, the tips of these were cut under the microscope by means of a sharp sterilised scalpel. Each hyphal tip so obtained was grown separately in nutrient medium.

Morphology of the Organisms

(i) *The Fungus*

The mycelium on solid media is mostly extra matrical producing a vigorous, white, aerial, fluffy and luxuriant growth. On oat agar intra matrical hyphae are also present. Growth is cottony and quickest if incubated between 25°C. to 32°C. Below 16°C. the growth is sluggish. The hyphae are long, fairly coarse, measuring 4·8 μ to 6·9 μ in width with an average of 6 μ. They are very

granular in character, coenocytic when young; septa appear in old cultures. Branching of the hyphae is irregularly monopodial.

The oogonia, (Text figs. 1, 2, 3 and 4) measuring 19 μ to 23 μ in diameter, are acrogenous or lateral. The oospores (Plate 1, fig. 5) are smooth differentiated into ooplasm and periplasm. Antheridia (Text fig. 5) are usually diclinous and clavate.

Sporangia are terminal as well as intercalary, measuring 19 μ to 26 μ and contain a varying number of oospores. (Text figs. 6, 7, 8 and 9).

The morphology of this strain of *Pythium* is more or less similar to the well established species: *Pythium aphanidermatum.*

(ii) *The bacteria*

I. Small organism, almost oval in shape, gram negative small colonies — 1 mm., translucent, irregular in outline, moist, dirty yellow in colour, non-sporing. Does not ferment sugars. Grows well on ordinary agar at normal oxygen pressure.

II. Large organism, rounded ends, occur in chains, gram negative, large colonies, dry scaly, irregular outline, yellowish opaque. Spore bearing-oval-central spores. Ferments glucose and maltose, does not ferment lactose. Grows well on ordinary agar under normal oxygen presssure, forms a surface pallicle on liquid media.

Inoculation Experiments

Detailed inoculation experiments were carried out by using healthy radish plants to determine the parasitic nature of the fungus, the mode of infection and the rate of destruction of the invaded tissues. Both root and leaf infections were attempted.

During the course of survey for collecting samples of diseased radish in natural condition and also while investigating pathogenicity of the fungus, it was apparent that temperature and moisture were two very important factors controlling the incidence of the disease. A detailed experiment on this aspect was therefore started which has reached only the preliminary stage. For the inoculation experiments described here, the soil was always kept moist and constant humid atmosphere maintained and the temperature was maintained at about 25°C.— the optimum for the growth of fungus — except where otherwise stated.

Root Infections

(i) *Relative pathogenicity of Pythium and bacteria*

An experiment was first carried out to test the pathogenicity of the bacteria I and II and the *Pythium* isolated from the diseased material. Radish plants from which leafy portions were detached with a sterilised knife leaving petiolar stumps on the crown of the hypocotyl were utilised for the experiment. The tap roots, about 0·75″ to 1·0″ in diameter and 6 inches long were thoroughly washed in a concentrated solution of borax for ten minutes, then re-washed with sterilised water to remove all traces of borax from the external surface of the radish roots. The roots were then steeped in mercuric chloride solution (1 : 1000) for 3 to 4 minutes, washed in repeated changes of sterile water and transferred to sterilised tubes of suitable bore containing moist cotton at the base.

For inoculation, a small plug of tissue was removed from the radish roots by means of a sterilised corkborer as described by Granger & Horne (1924) for apple inoculations and the plug was replaced after introducing the inoculum of the pathogen. The injured region was then sealed with a mixture of sterilised paraffin and vaseline. The tubes were plugged with sterilised cotton wool after the inoculation. The organisms after being introduced in the host tissue were incubated at the room temperature which ranged from 25°C to 28°C.

Pure cultures of bacteria and *Pythium* were utilised for the experiment.

Three different sets of inoculations were made in which the following combinations of inoculum were used : —

I. Set : Mixture of bacteria I and II.

II. Set : *Pythium* and mixture of bacteria I and II.

III. Set : *Pythium*.

Ten replicates of each set of inoculations were tried.

In 4 days, when the rot due to the fungus was appreciable, the entire lot was examined. The rotted mass was segregated and separately weighed. The results are embodied in Table I.

TABLE I.

Showing the amount of rot produced in the radish roots by *Pythium* and bacteria separately and in combination, at 25°C. — 28°C. and saturated moisture condition.

Serial No.	Organism inoculated		
	Bacteria weight of rotten tissue	Bacteria plus *Pythium aphanidermatum* Weight of rotten tissue	*Pythium aphanidermatum* Weight of rotten tissue
	gms.	gms.	gms.
1. ..	1·6	8·2	5·8
2. ..	—	6·2	12·0
3. ..	2·2	3·0	14·0
4. ..	—	5·0	7·5
5. ..	2·1	8·1	12·0
6. ..	1·8	15·0	5·0
7. ..	1·0	7·5	5·2
8. ..	—	9·1	6·9
9. ..	—	8·6	7·0
10. ..	—	5·5	12·0
Total ..	8·7	76·2	87·4
Average ..	0·87	7·62	8·74

It will be seen from Table I where the first set relates to inoculations with bacteria, that only in five cases out of ten, very slight infection was visible. A careful examination of the rotted tissue of the other five showed that the bacteria inoculated had invaded only the tissue which had been destroyed during the operation and was, therefore, not taken into account. The rot produced in the five radishes ranged from 1·0 gm. to 2·2 gms. in the average of 1·7 gms. This negligible amount of rot, indicated that the bacteria were not responsible for the disease.

In the second set which refers to inoculations with a mixture of bacteria and the fungus the amount of rot produced was 76·2 gms.

In the third set where only the fungus was inoculated, the rotting was considerable. The total amount of rot produced in 10 replicates was 87·4 gms. The amount of rot in the different radishes varied from a maximum of 14 gms. in one case to the minimum of 5 gms. Three radishes showed 12 gms. of rot, the rest varying between 5·2 – 7·5 gms.

It was also noticed that the rot produced is essentially similar to that found in fields in the natural condition both in colour and the peculiar offensive smell.

The experiment conclusively showed that the soft rot disease is not caused by bacteria but by the *Pythium*, the very slight pathogenic activity shown by the bacteria being negligible.

(ii) *Pathogenicity of Pythium under field condition.*

A number of radish plants were grown in pots. Twelve healthy plants which had attained the state of maturity were selected for the experiment. The method of inoculation was exactly similar to that employed for the previous set using only the *Pythium*. The inocula of the fungus taken from the growing region of a monohyphal culture were introduced into the portions of the root which usually peeps out of the soil. A small plug of the tissue was removed out from the potted plants by means of a corkborer and replaced after introducing the pathogen. The plants were kept under observation. Another set of 12 plants was treated similarly but without fungal inocula and served as controls.

It was observed that rotting began within 24 hours, indicated by the appearance of water soaked area around the inoculated region and subsequent appearance of luxuriant white mycelium over the infected tissue. The entire radish was reduced to pulp within a week. The leaves showed the effect in the form of etiolation and wilting on the third day and drooped down and broke off to the ground as more and more of the tissues disintegrated.

Within a fortnight, the rotting of the cortical tissues was such that when plants were pulled out of the soil, a mesh of apparently unaffected vascular system came out leaving the disintegrated mass of cortical tissues behind.

(iii) *Penetration of Pythium through uninjured surface*

(a) *Tap root*

Results of the inoculation experiments hitherto carried out showed that it was possible for the *Pythium* strain to attack the radish host when inoculated into the cortical tissues. In order to find out if the parasite could attack through the uninjured epidermal layer or through uninjured secondary rootlets, further experiments were carried out.

Radishes were carefully uprooted and rinsed in sterile distilled water, after surface sterilization with mercuric chloride, so that the epidermis remained completely uninjured. Radishes from which leafy crown was removed aseptically leaving the root with the petiolar stumps were utilised for the experiment. Ten of these were then placed in moist chambers and inocula of *Pythium* was placed on the uninjured surface. The radish tap roots with inocula placed on the cut surface served as control. All the plugged tubes with radish in them were then incubated at 28°C.

In the control experiments, the first indication of the rot was evidenced 8 hours after the inocula had been placed, which was discernible from the change of the surrounding white region of the tissues into dull yellow colouration: the rot continued to increase and after 16 hours, substantial progress of the rot was seen accompanied by fluffy mycelial growth on the tissues.

In the other set, where the inoculum was kept in contact with the uninjured skin, the first indication of the rot was observed 16 hours after the inocula had been contacted, which was evident by the change in colour and softer feel of the area around the inocula. The rot progressed and in another 12 hours profuse fluffy mycelial growth was visible (Plate 1, fig. 3).

Similar experiments were repeated with ten potted plants to confirm the results under more natural conditions where mechanical handling and other treatments of the radish did not come into play. The region below the hypocotyl which usually remains peeping out of the soil, was swabbed with absolute alcohol to clean it of extraneous organisms and inocula from a recent culture of *Pythium* placed on it. The soil was kept moist and the entire pot with the plant was kept covered with bell jars.

The results observed were similar to those observed with the uprooted radish described above. Rot accompanied by fluffy mycelial growth was visible after 28 hours, as seen in the previous case.

After the initiation of the infection, the advance of the rot was essentially similar in all the sets of inoculation. The experiment clearly demonstrated that the fungus could penetrate the host through the uninjured piliferous tissues and that the piliferous layer showed a certain amount of resistance to the entry of the hyphae.

The hyphae were found entering through any part of the piliferous layer and growing freely in the tissues. The sections of

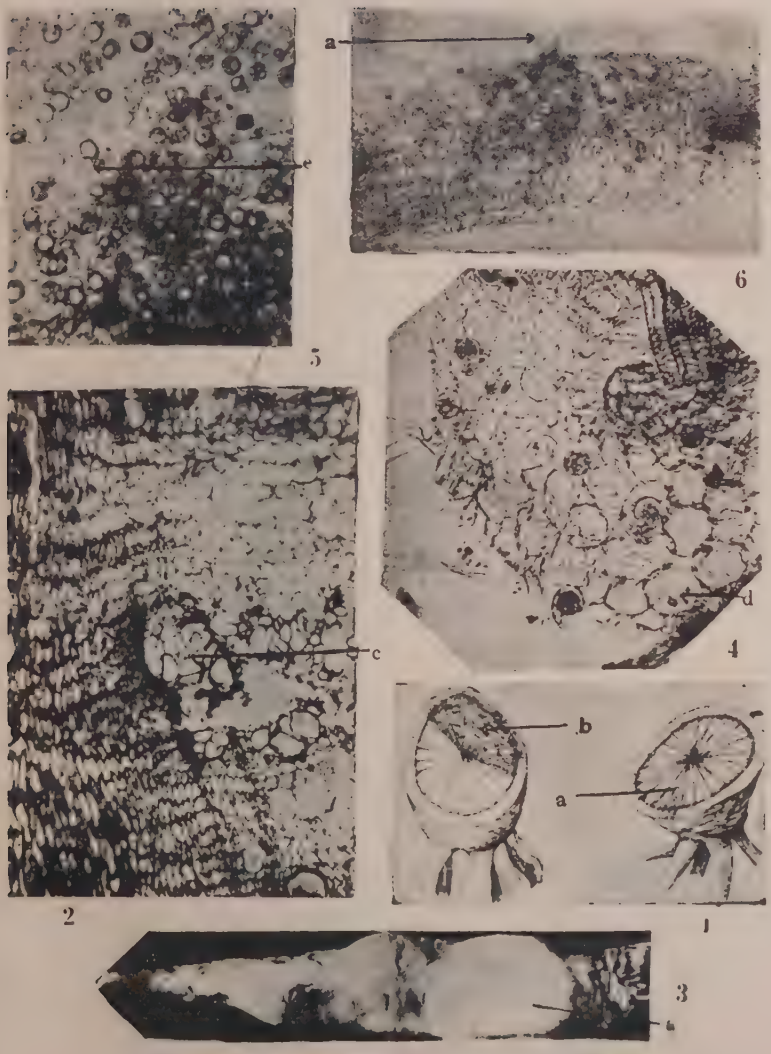


PLATE I

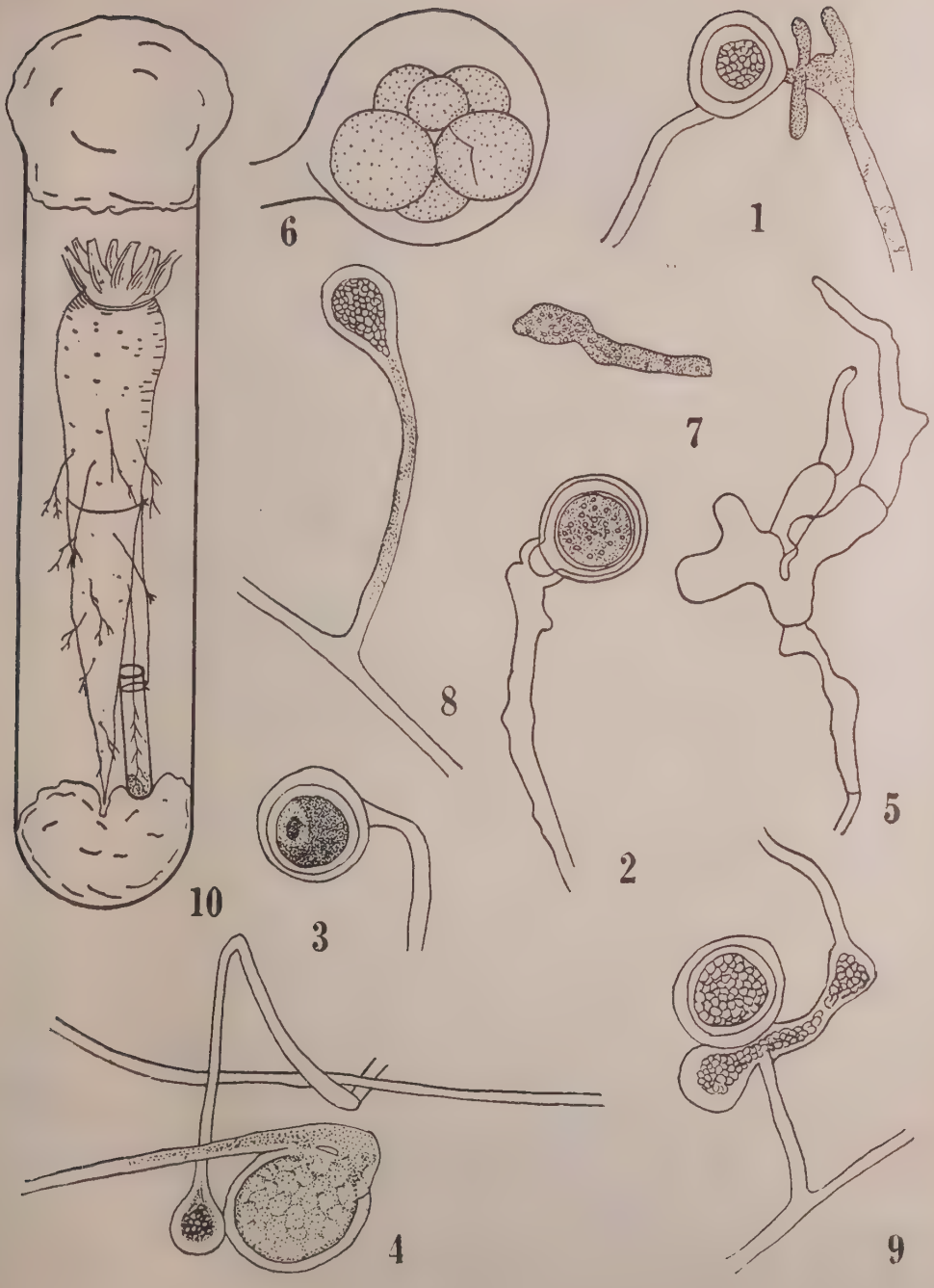


PLATE II

Text-figs. 1—4, Oogonia; Text-fig. 5. Antheridia; Text-figs. 6—9, Sporangia (all × 600); Text-fig. 10, Sketch showing the method of contacting secondary tertiary roots with inocula.

the diseased part revealed the presence of hyphae in the lumen of the vessel (Plate 1, fig. 2).

(b) *Secondary and Tertiary roots*

An experiment was next carried out to ascertain if the fungus could penetrate the tap root tissues through finer secondary and tertiary rootlets under normal conditions.

For this purpose, radish tap roots from which the leaves had been aseptically removed were placed in sterilised glass tubes (7·5″ × 1·75″) with moist cotton wool at the base, after necessary surface sterilisation and the tube plugged with sterilised cotton wool. The tap root threw out small hairy adventitious roots which developed to as much as 2″ in length after 48 hours.

Tiny glass tubes (0·5 cm. × 5 cm.) were sterilised and a small quantity of oat-agar medium was placed at the base of the tube over which were planted inocula from a recent culture of *Pythium*.

The slender growing rootlets from the radish as described above were contacted with the inocula and the small tube was loosely tied to the main radish root and the entire radish along with the small tube slipped into the larger tube in which originally the radish was contained and plugged with cotton wool (Text-fig. 10).

In all 12 replicates were tried and incubated at 28°C.

The rootlets so treated developed a dull yellow colour after 24 hours, indicating that the infection had been initiated by the entrance of the hyphae into the host tissue. This was confirmed by the microscopical examination of the rootlets which revealed the presence of fungal hyphae in the cortical cells (Plate 1, fig. 4). As a result of this initiation of the infection, the growth of the rootlet ceased. The infection progressed further, and in eight days the entire tap root was involved and finally the whole mass was covered by fluffy growth of the mycelium.

The experiments conclusively demonstrated that *Pythium*, the causal organism of soft rot was able to infect through uninjured surface and produce the disease.

B. Leaf Lamina Inoculations

Infection through injured and uninjured leaves

Having ascertained that the fungus can infect through roots, experiments were made to find out if the infection would occur through the lamina and petioles of the leaves.

For these experiments potted plants which had attained a state of maturity were employed. In the case of lamina the inocula from a fresh young culture were left in contact with the bruised leaf surface in the presence of moisture. The dorsal side of the leaf was bruised lightly by scraping with a sterilised scalpel. Twelve pots were utilised for this set of experiments and another set of 12 potted plants were used where the inoculum was left on the dorsal side of the leaf without injuring the leaf. The experimental pots were kept moist in both the sets.

The infection was initiated after 12 hours in the injured leaves while in the uninjured leaves the rot was initiated after 20 hours. The first symptom of the infection was the change of the colour of the region around the inoculum from bright to a dull green which subsequently changed into yellow. With the advance of the infection, the lamina assumed water soaked appearance and became flaccid; the disorganised cells showed a wet rot and consequent crumbling down of the tissues.

Histological investigation showed that the hyphae could pierce through the epidermal cuticle. The hyphae tip swelled up slightly before entering the epidermis (Plate 1, fig. 6).

These experiments were also repeated by placing the inocula in the same way on the ventral surface of the leaf under similar experimental conditions. The hyphae entered the leaf tissues both through stomatal openings and the epidermis.

These experiments showed that as in the root surface in the leaf surface too, the hyphae can penetrate through the uninjured epidermis, acting as a true parasite, although in the bruised surface the infection occurs more readily. It is, thus, apparent that both in root and in leaves the epidermal tissue offers some resistance, but is unable to check the entry of the fungus.

Discussion

Pythium has been found to be parasitic on a number of garden and vegetable crops both in India and elsewhere. It is one of the organisms which causes the 'damping off' disease in various cruciferous plants. There is extensive literature on this genus detailing the numerous hosts from different parts of the world. Middleton (1943) has published a comprehensive account of the taxonomy, host range and geographical distribution of the genus *Pythium*.

Edson (1915) has recorded a species of *Rheosporangium* (now regarded by Fitzpatrick (1923) as a synonym of *Pythium*) as being parasitic on sugarbeets and radishes in the United States of America. Vaughan (1924) observed a black rot of radish in Indiana caused by *Pythium aphanidermatum,* while Bunting (1925) attributed to it the 'damping off' of tobacco in Africa.

Drechsler (1925-26) reported a cottony leak of cucumbers (*Cucumis sativus* L.) caused by this species of *Pythium.* He also considers this to be the causal organism of a cottony leak of *Solanum melongena* in Florida. Cheney (1932) has described root-rot of broad beans in Victoria due to *Pythium.* Kreutzer and Durrel (1938) made a detailed study of the rot of mature tap root of sugarbeet caused by *Pythium Butleri.* Weimer (1940) indicated that a species of *Pythium* was the causal organism of root rot of winter peas and vetches. Davis (1941) reported 'damping off' of long leaf pine due to *Pythium.*

In India Subramaniam (1919) described a *Pythium* disease of ginger (*Zinziber officinale* Roscoe.), tobacco (*Nicotiana tabacum* L.) and papayas (*Carica papaya* L.) and subsequently Mitra and Subramaniam (1928) found *Pythium aphanidermatum* to cause damage to different members of the *Cucurbitaceae. Pythium* has been found to cause a malodorous rot of water melon (Kheswalla, 1936) and a wet rot of tobacco seedling (Venkatarayan, 1937). Galloway (1937) reported that this genus was parasitic on hemp. Very recently Bhargava (1941) has also isolated *Pythium aphanidermatum* from *Carica papaya* causing stem and foot rot in an epidemic form.

In the present paper is described a soft rot of radish caused by a species of *Pythium.* So far as is known to the author this disease has not been recorded before in India. The fungus has been isolated from a number of diseased radish plants (*Raphanus sativus* L.) more frequently during the rainy season and on rare occasions in the early winter. A careful survey has shown that the disease although common does not occur in an epidemic form.

The general symptoms of the disease are similar to those described by Mitra and Subramaniam (1928) for the fruit rot of *Cucurbitaceae.* The newly invaded tissues exhibit a water soaked appearance, dirty yellow in colour, but as the decay progresses the infected tissues become soft and pulpy turning brown in colour and emitting an offensive odour. The symptoms of the rot were, however, slightly different from what have been described by Kreutzer and Durrell (1938) for sugarbeet. The rot in the sugar-

beet was not exactly 'soft' but in all other essential details it was similar to the rot of radish described here.

The disease has been found to be associated with *Pythium* and two forms of bacteria. Each of these organisms has been isolated and studied in culture and their pathogencity tested by various inoculation experiments. The inoculation experiments have conclusively proved that *Pythium* is the causal organism, as this fungus freed from bacteria can independently cause disease in almost 100 % cases whether introduced into the tissues by wounding or placed on the uninjured surface. The two bacteria found in association were found from inoculation experiments to be saprophytes growing on the tissues rotted by *Pythium*. When separately inoculated into healthy radish root the bacteria showed only a very negligible amount of rotted tissue. Again the combined pathogenicity of *Pythium* and the two bacteria proved to be almost the same as that of *Pythium* alone. The fungus thus is the causal organism and the bacteria thrive on the rotting tissue only as saprophytes.

Under natural conditions in the fields the infection of radish plants may occur through the tap root and secondary or tertiary roots. From a careful survey of the diseased plants under natural conditions it was found that mostly the collar of the tap root above the soil was the first to be affected. The fungus usually enters the radish plant at or near the soil level from where it travels below into the root and upwards into the shoot. Lehman and Wolf (1926) made a similar observation with respect to the mode of infection by *Pythium* in the case of soyabean. The infection of the rootlets and those serving as a focus does not occur in many cases in nature. Nor has the infection through leaves been ever found in fields; though both the rootlets and the leaves are susceptible to artificial inoculation.

Inoculation experiments in the laboratory and field conditions have shown that the fungus can readily penetrate into the tissues when in contact with the collar of the tap root. In all the experiments carried out both with injured and uninjured surfaces the infection has invariably taken place in cent per cent cases. The infection of radish through the secondary and tertiary roots has been demonstrated experimentally. The fungus parasitises the fine rootlets but it is only after considerable time (8 days) that the infection travels into the tap root. Once it has gained entry into the tissues of the main tap root, the progress of the disease is very rapid. The entry of the fungus through the rootlets is largely conditioned by favourable moisture and temperature conditions.

As has been already stated the infection of radish through leaves hardly ever occurs in nature. But very successful infection through both the dorsal and ventral side of the leaves has been produced by artificial inoculation. The fungus is able to penetrate into the tissue of the host through leaf lamina. The entry is affected both through the stoma and the epidermis. In those cases where the fungus enters through the epidermis, the infecting hyphae puncture the epidermis; the tip of the hypha swells up prior to the penetration. This swelling of the hyphal tip is not such that can strictly be regarded as an appressorium. The swollen hyphal tip exerts a mechanical pressure which plays an important part in the penetration of the host. Brown and Harvey (1937) conclusively demonstrated this phenomenon in germ tubes of *Botrytis cinerea*. A similar observation has also been recorded by Hawkins and Harvey (1919) dealing with *Pythium* infections of potato. The general symptoms of the infected leaf of radish are comparable to those described by Middleton, Tucker and Tompkin (1938) in the *Pythium* infected leaves of *Begonia* where the leaf lamina has been observed to become water soaked and flaccid resulting in subsequent abscission of the infected leaves.

A comparison of the results of inoculations through injured and uninjured surfaces of roots and leaves shows that the fungus as stated before is able to parasitise the host tissue under both conditions. The penetration of the hyphae, however, through injured surface is more rapid when the hyphae are already inside the cortical tissues or on the injured epidermis than when the fungus has to enter the host through the uninjured surface. But the ultimate result in both the cases is identical. In the leaves the fungus can penetrate both through the stoma pore and by puncturing the epidermis.

The fungus having penetrated the host tissues, makes a rapid progress killing the tissue in advance of the hyphae. The middle lamellae of the cells dissolve separating individual cells. The hyphae are usually intercellular; intracellular hyphae were also observed. In completely rotten radishes the hyphae break through the vascular walls and penetrate inside the vessels. In the infection through the leaf or petiole the fungus travels through the parenchymatous cells into the vessels and from there passes into the tap root.

The infection and invasion of tissues by the fungus are controlled by moisture and temperature. Thus the disease is usually found in soggy soils and during the rains when atmosphere humidity is the greatest. The relative scarcity of the disease in winter

can be attributed both to the low temperature and lack of adequate moisture.

Summary

The paper deals with a hitherto unrecorded disease, the soft rot of radish (*Raphanus sativus* L.).

The disease occurs usually in the crop produced during the rainy season and only rarely in early winter crops.

The symptoms of the disease have been described. The affected tissue becomes soft and pulpy leading to a complete disintegration of the root in the final stage; the leaves are also affected and become water soaked and flaccid, finally dropping off through disintegration of the petiolar tissues.

Inoculation experiments have conclusively proved that the soft rot is caused by *Pythium aphanidermatum.*

There are two forms of bacteria associated with the rot, which have been proved to be the secondary putrifying organisms.

The fungus is soil-borne and usually infects the tap root of the host at or near the soil level. Infection through secondary or tertiary roots or rootlets is rare. Direct infection of the leaf although seen under experimental conditions does not occur in nature. Excessive moisture and a temperature range between 28°C – 32°C are favourable for the incidence and spread of the disease.

The morphology of the fungus and the bacteria has been described.

Acknowledgment

The author is grateful to Dr. S. N. Das Gupta, Ph.D., D.Sc. (London), D.I.C., for his guidance and helpful criticism during the course of this work.

LITERATURE CITED

Bhargava, K.S. (1941): *Pythium aphanidermatum* (Edson) Fitz. On *Carica papaya.* Curr. Sci., Vol. 10, pp. 212-13.

Brown, W. (1924): Two mycological methods — II. A method of isolating single strains of fungi by cutting out a hyphal tip. Ann. Bot., Vol. 38, pp. 401-404.

Brown, W. and Harvey, C.C. (1927): Studies in the Physiology of Parasitism X. On the entrance of Parasitic Fungi into the Host Plant. Ann. Bot., Vol. 41, pp. 643-661.

* Bunting, R.H. (1925): Report of the mycological section for the year ending 31st March, 1924. Rept. Agr. Dept. Govt. Gold Coast 1923-24; pp. 32-33. (Rev. App. Myc., Vol. 4, p. 463).

* Chaney, G.M. (1932): *Pythium* root rot of broad beans in Victoria. "Aust. Journ. Exp. Biol. and Medical Science, Vol. 10, pp. 143-155.

Davis, William C. (1941): Damping-off of longleaf pine. (Abstr.). Phytopathology, Vol. 31, p. 1011.

Drechsler, C. (1925): The cottony leak of cucumbers caused by *Pythium aphanidermatum*. J. agric. Res., Vol. 30, pp. 1035-1042.

Drechsler, C. (1926): The cottony leak of egg plant fruit caused by *Pythium aphanidermatum*. Phytopathology, Vol. 16, pp. 47-49.

Edson, H.A. (1915): *Rheosporangium aphanidermatus*, a new genus and species of fungus parasitic on sugarbeets and radishes. J. agric. Res., Vol. 4, pp. 279-296.

Fitzpatrick, H.M. (1923): Generic concepts in the Pythiaceae and Blastocladiaceae, Mycologia, XV, p. 166.

Galloway, L.D. (1937): Report of the Imperial Mycologist. Sci. Rep. Agr. Res. Inst., New Delhi, 1935-36, pp. 105-111.

Granger, K. and Horne, A.S. (1924): A method for inoculating the apple. Ann. Bot., Vol. 38, pp. 213-216.

Hawkins, I.A. and Harvey, R.B. (1919): Physiological Study of the Parasitism of *Pythium de Baryanum* Hesse. On the Potato Tuber. J. agric. Res., Vol. 18, pp. 275-294.

Kheswalla, K.F. (1936): Fruit diseases in Baluchistan 587. Agr. Livestock, India, Vol. 6, pp. 204-215.

Kreutzer, W.A. and Durrel, L.W. (1938): Rot of nature tap of sugar beet caused by *Pythium Butleri*. Phytopathology, Vol. 28, pp. 512-514.

Lehman, S.G. and Wolf, F.A. (1926): *Pythium* root rot of soyabean. (Abstract). Phytopathology, Vol. 16, p. 640.

Middleton, J. T. (1943): The taxanomy, host range and geographic distribution of the genus *Pythium*.. Memoirs of the Torrey Bot. Club., Vol. 20, No. 1.

Middleton, J.T., Tucker, C.M., and Tampkins, C.M. (1938): *Pythium* Disease of Fibrous-rooted Begonia. (Abstract). Phytopathology, Vol. 28, p. 672.

Mitra, M. and Subramaniam, L.S. (1928): Fruit-rot disease of cultivated cucurbitaceae caused by *Pythium aphanidermatum*. (Eds.) Fitz. Mem. Dept. Agric. India, Bot., Vol. 15, No. 3, pp. 79-84.

Subramaniam, L.S. (1919): A *Pythium* disease of ginger, tobacco and papaya. Mem. Dept. agric. India, Bot. Ser., Vol. 10, No. 4, pp. 181-194.

* Vaughan, R.E. (1924): Diseases of field and vegetable crops in the United States in 1923. Pl. Dis. Reptr. Suppl. U.S.A., 34, p. 148.

Venkatarayan, S.V. (1937): Report of the work done in the mycological section during the year 1935-36. Administration Report of the Agriculture Department for 1935-36. Ann. Rep. Mysore, pp. 51-55.

Weimer, J.L. (1940): Root rot of Austrian winter peas and vetches. (Abstract). Phytopathology, Vol. 30, p. 708.

* The original papers were not consulted.

EXPLANATION OF PLATE

Plate 1

Figure

1. A diagrammatic sketch of a diseased and healthy radish in cross section, (a) a healthy root, (b) partly diseased, the shaded part indicating the infected region.
2. Tap root, × 75. (c) hypha in the lumen of vessels and cells.
3. Photograph of radish tap root with fluffy mycelial growth (a) produced in 28 hours from inoculum placed on uninjured surface. × 0·50.
4. Photomicrograph showing hyphae in the rootlet (d) (transverse section). × 150.
5. A Photomicrograph showing oospores on oat meal agar (e). × 105.
6. Photomicrograph showing hyphae in the leaf (transverse section). (a) swelling of the infecting hyphae resting on the epidermis.

Fig. 1

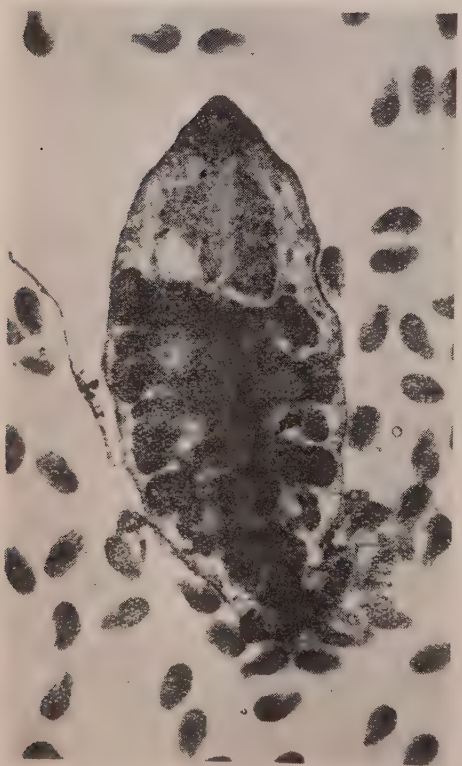


Fig. 2

Fig. 3

A RARE CASE OF COMMENSAL IN A POLYCHAET, AMPHINOME ANATIFERA N.SP.

BY

B. KRISHNAMOORTHI, B.Sc. (HONS.) AND A. DANIEL, B.Sc.

Zoology Laboratory, University of Madras

Introduction and Historical

Except for Verrill's (1885) reference to *Amphinome lepadis* "taken on floating timber in the gulf stream, among goose barnacles *Lepas*," and his figures published by Hartman in 1944, there is no detailed account of any polychaet living within the body of cirripedes. Therefore, when a species of *Amphinome* was found inhabiting the brood-pouch of *Lepas anatifera* (Fig. 1.) collected off the coast of Madras, a thorough study of the morphology of the worm was made. Verrill's description of *Amphinome lepadis* gives the following characters: head being small and slightly bilobed in front; the caruncle cordate with thickened edges; the head bearing five large antennae, two front antennae, two lateral antennae and a median antenna; the branchiae occurring from the third segment and being large and arborescently branched; each segment bearing a dorsal and a ventral cirri, a single kind of white and brittle setae; the anus situated dorsally. The present worm, however, exhibits features all its own, such as (1) the almost complete disappearance of neuropodial lobes, (2) the presence of peculiar club-shaped, scythe-shaped and spine-like setae, and (3) the mouth being a cresent-shaped slit, usually circular in free living forms. The above are probably characters correlated with its habitat, and point to the form belonging to a new species.

Material and Methods

One adult and six immature forms were collected from the brood-pouches of seven barnacles, taken alive and preserved, from the beach of Madras. The adult was found within the mantle cavity, occupying completely the interspace between the prosoma proper of the host and the peduncular apex, with its ventral surface in very close contact with the prosoma. About two cms. away from the base of the adductor suctorum muscle ventrally is the anterior end of the worm, while the posterior end terminates at the base of the caudal appendage. (Fig. 1.) All the immature

forms of different ages were collected from the inner surface of the membrane of the brood chamber, lying in the inter-spaces between the eggs. The specimens were photographed *in situ*. Later they were stained in Borax Carmine and cleared in cedar-wood oil and both their external and internal morphology were studied. The specimens will be lodged at the Indian Museum.

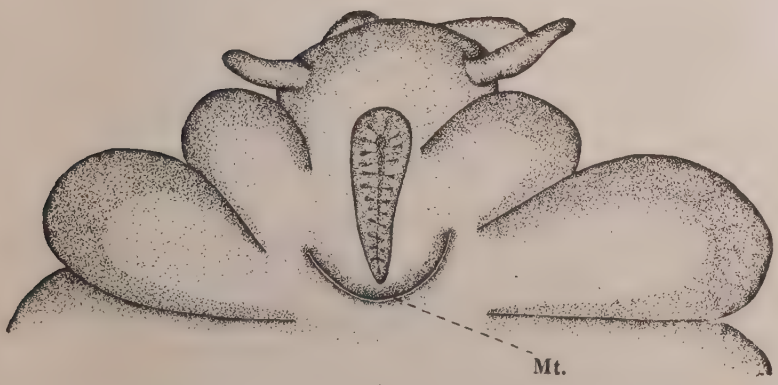
The Adult

The worm is 20 m.m. long and 5 m.m. broad at its greatest width. It is uniformly flesh coloured preserved in formalin. It is squat and grub-like. The skin is smooth all around showing twenty-seven segmental grooves. Anteriorly and posteriorly the body tapers, the segments being narrower. The front end is more pointed than the hind end. Typically the body is oval in cross-section, the dorsal side being broader than the ventral.

The conical prostomium, though retracted into the two anterior segments is distinctly visible on the dorsal side. (Fig. 4.) It is almost hidden by the adjacent segments especially in a ventral view. (Fig. 5.) Both the anterior and posterior margins of the prostomium are entire. It bears two short, small, palpar tentacles set close to the median line on the dorsal and ventral sides. Though they seem to arise from the eyes they are a little anterior to them. There are two eyes on each side. (Fig. 4.) They are situated on the dorsal side at the posterior corners of the prostomium, almost continuous with each other. The caruncle is a small, cardiform organ on the dorsal side of the prostomium lying at its posterior extreme corner. Ventrally is another pestle-shaped organ, located in the caruncular region. Anteriorly it is broader and tapers posteriorly, terminating just in front of the mouth and is much plicated. The mouth is a ventral crescent-shaped slit with its convexity directed posteriorwords, a feature unknown in any free living form. (Fig. 5.) Anteriorly it is bounded by the palpar area, laterally by the first setigerous segment, the second setigerous segment forming its posterior border.

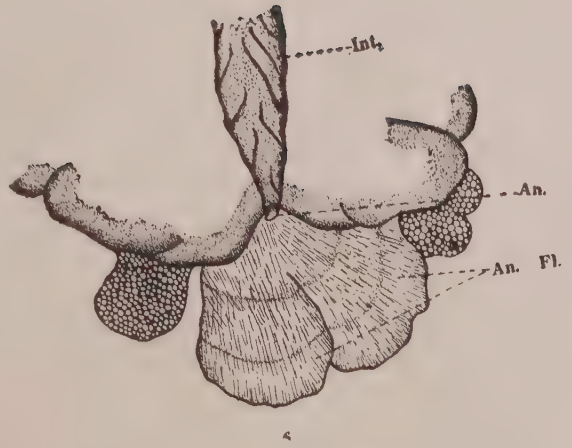
The full complement of the parapodium is absent, the notopodium alone being well developed. In the first setigerous segment even this is illdefined. In segments twelve to fifteen the notopodial and neuropodial lobes as well as the setae are present and in such segments the notopodial and neuropodial lobes are widely separated from each other by a curved inflated surface, a feature not met with in the free living forms where the notopodium as well as the neuropodium are well developed in all the segments. In addition to the possession of ten to fifteen long, bristle-like setae,

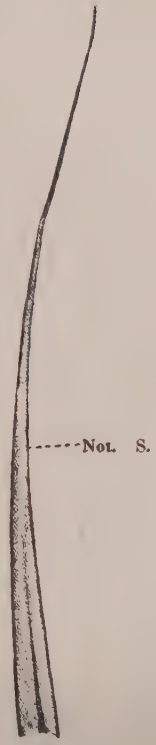
4



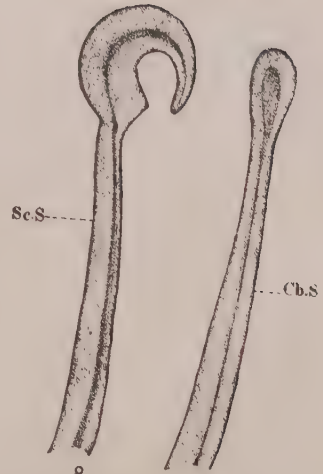
5

Figs. 4 and 5





7



8 9

Figs. 6—9

the notopodium also bears the branchiae dorsally. The branchiae are in clusters, but are limited to its distant dorsal tip only. In the preserved specimen they appear pale. While they are simple, finger-shaped processes in the first, twentysixth, twentyseventh and twentyeighth segments, they branch out profusely in the other segments; the number of branches reaching a maximum in the middle ten to twenty segments. They are not so conspicuous as in the free living forms where they occupy most of the dorsal surface of the body. The notopodial setae are deeply set, fine, hair-like and transparent structures. Each notopodial seta is thicker at the base and tapers gradually to a point at its free end and unlike that of free living forms it is non-serrated. (Fig. 7.) Apart from the branchiae and the setae, the notopodium does not bear the dorsal cirrus which is a characteristic feature in the free living forms. Though the neuropodial lobes are absent, there are however, neurosetae and they are of two kinds: (i) the hook or the scythe-shaped setae and (ii) the club-shaped setae. (Figs. 8 & 9). In the preserved form they are not seen projecting out but in the cleared specimen they can be seen deeply embedded and directed postero-anteriorwards. They are also non-serrated. The anus is terminal but is surrounded by a pair of fan-like flaps. (Fig. 6).

Except in the form of a bilobed mass in the carunclar region nothing much can be made out of the nervous system. Even when stained and cleared in cedarwood oil, the thickness of the worm did not permit the vascular, muscular, excretory and reproductive systems to be examined. Only the alimentary system could be made out as a much diverticulated canal.

The Worm with 8 Segments

The smallest worm recorded measured about 3 m.m. in length and 1 m.m. broad at its greatest width. (Fig. 2). It is brownish in colour and is transparent. The skin is smooth and about seven segmental grooves are discernable under high power indicating eight segments. (Fig. 13). The segments are constricted anteriorly while they are broader at the posterior end. The postomium is very distinct and not hidden by the adjacent segments. It bears two pairs of poorly developed, knob-like palpar tentacles. Two pairs of eye are also distinct. The caruncle is not well formed. Ventrally the mouth is a transverse slit at the base of the prostomium extending from one margin to the other laterally. (Fig. 12).

The notopodium bears only four setae in each segment. The neuropodial lobes are completely absent and there is not even a trace of it in any segment. The neurosetae are but a pair, one

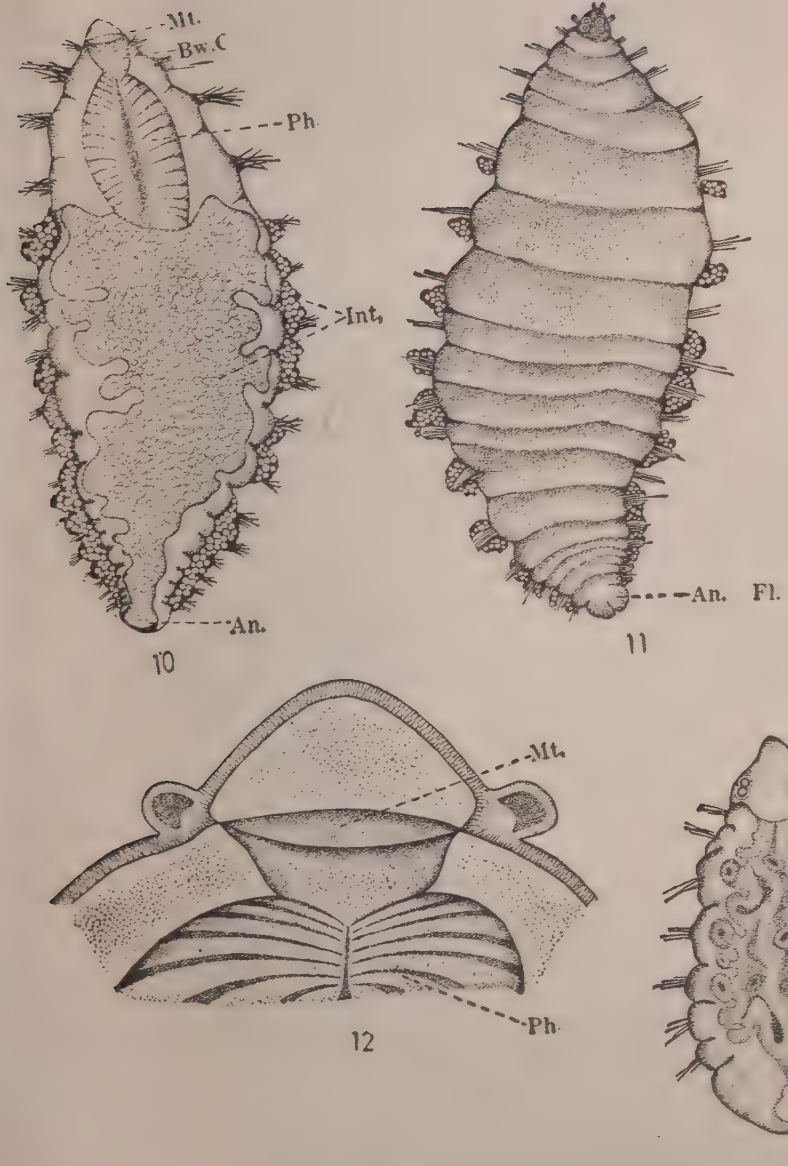
club-shaped and the other hook-shaped. Branchiae are completely absent. In the cleared specimens the alimentary canal can be distinctly made out. The mouth opens by a short buccal-cavity into a bulbous pharynx. The typical mouth parts are absent and the bulbous pharynx is thrown into many transverse folds. It opens posteriorly at the 2nd segment into the intestine which is profusely diverticulated. The diverticula can be seen extending laterally up to the margins of the parapodia. Before opening out by the anus this much branched intestine narrows into a short, straight tube. The anus is terminal.

The Worm with 18 Segments

It is 7 m.m. long and 2 m.m. in diameter at its broadest region. It is also transparent and dark brown in colour. (Fig. 3). The skin is smooth showing seventeen segmental grooves. (Fig. 11). As in the adult form the anterior and posterior segments are narrower. The prostomium remains conspicuous. The notopodium bears a bundle of a single kind of setae. The branchiae are well developed only in the posterior segments and are deep pink in hue. They are absent in the three or four anterior segments. The bulbous pharynx occupies four segments. (Fig. 10).

Remarks

Taxonomic : — It appears that only about 12 valid species of the genus *Amphinome* are known. Of these twelve *Amphinome nitida, Amphinome praelonga* (Haswell, 1878); *Amphinome longsetosa* (Horst, 1886) ; *Amphinome pallasii* (Ehlers, 1888); *Amphinome djiboutiensis* (Gravier, 1902); *Amphinome maldivensis* (Potts, 1910); *Amphinome nigrobranchiata, Amphinome pulchra* (Horst, 1912); *Amphinome rostrata* (McIntosh, 1923); *Amphinome jukesi* (Monro, 1924) are characterised by the branchiae commencing from the 3rd segment and bearing serratious setae, whereas the present form bears branchiae in all the segments and non-serratious setae. *Amphinome lepadis* (Verrill, 1885) on the other hand is characterised by the body being stout, it being 70 to 100 m.m. long and 12 m.m. broad; head being small and slightly bilobed in the middle; caruncle being cordate with thickened edges; the head bearing two large front antennae, two equally large lateral antennae and a median antenna; each segment having prominent ventral as well as dorsal cirri; the setae being of a single kind, white and brittle; and the branchiae beginning from the third setigerous segment, deep brown in colour and arborescently branched, features not met with in the present form. The



Figs. 10—13

remaining species *Amphinome microcarunclata* (Treadwell, 1903) is peculiar in having the branchiae commencing from the 8th segment, in the possession of a dorsal cirrus arising at the base of a tuft of setae, about ¾ as long as the setae, in the ventral cirrus being slender but shorter than the ramus, features not present in the present form. Further this form is of interest in its possession of 2 pairs of distinct eyes; in bearing a peculiar pestle-shaped structure ventrally in the carunclar region; in the mouth being a crescent shaped slit; and in the alimentary canal having numerous diverticula — features not met with in any of the species described.

Of the above twelve species, *Amphinome rostrata* and *Amphinome maldivensis* alone have been recorded from the Indian seas. They are characterised by features as shown in the tabulated account on pages 22 and 23.

From the above tabulated account it is evident that the present form is a new species not only in the possession of peculiar features of its own but in the peculiar habitat it has chosen. Hence this is treated as a new species, *Amphinome anatifera.* Flesh coloured. Smooth skin. 28 segments. Oval in cross-section. 2 pairs of tentacles. The median unpaired tentacle absent. 2 pairs of eyes. The caruncle small and cardiform. Ventrally a peculiar pestle-shaped structure is present. Mouth a crescent shaped slit. Notopodium alone being well developed. Branchiae in all the segments and in clusters in the posterior segments. The dorsal and ventral cirri absent. Notosetae are fine, hair-like, transparent structures. Neurosetae two kinds. Both non-serratious. Anus terminal, but provided with a pair of anal flaps. Brood pouch of *Lepas anatifera.*

Summary

1. The habitat, external morphology and such of the internal structures of the adult as can be seen through the skin are described.

2. A comparison of other valid species of the genus *Amphinome* with the present form, a new species, is given.

Acknowledgments

The authors take this opportunity to thank Dr. C. P. Gnanamuthu, M.A., D.Sc., F.Z.S., Director, Zoology Laboratory, University of Madras, for his guidance and help and Prof. R. Gopala Aiyar, M.A., M.Sc., Professor of Zoology, Andhra University for having revised the manuscript and offered valuable criticism and suggestions.

Characters	Amphinome maldivensis	Amphinome rostrata	Amphinome anatifera
Length ..	68 m.m.	———	20 m.m.
Breadth ..	11 m.m.	———	5 m.m.
No. of Segments ..	55	46—57	28
The worm ..	Grub-like; flesh colour; the ventral surface smooth; the dorsum wrinkled; tetragonal in cross-section.	Elongated and tetragonal; dorsal and ventral surfaces convex; the former having transverse grooves while the latter have rugose appearance and a median longitudinal groove.	Squat and grub-like; skin smooth; oval cross-section dorsum broader than the ventral surface.
Prostomium ..	Invisible from the dorsum.	Small and very indistinct.	Conical and distinctly visible from the dorsal side; hidden by the two anterior segments on the ventral side.
Caruncle ..	Slightly developed.	Small and tongue-shaped; attached in the middle but free at the edges.	Small, cardiform; on the dorsal side; lying at the posterior extreme corner of the prostomium.
Tentacle ..	A median tentacle at the base of the caruncle; a pair of lateral and a pair of median tentacles, the former arising from the base of the eyes.	Two tentacular cirri on the snout, conical and feruginous in appearance; two more cirri on the anterior border of cephalic region.	Two short, small palpar tentacles set close to the median line on the dorsal and ventral sides anterior to the eyes.
Mouth ..	The lips pressed together to form a heart-shaped mass.	Mouth opens inferiorly at the anterior border of the third segment; longitudinal in disposition.	Mouth ventral, crescent-shaped.
Parapodia ..	Well developed.	Well developed; dorsal cirrus arising from the posterior part of the bristle papillae; ventral cirrus very short.	No cirri, notopodium alone well developed; neuropodial lobes suppressed except in the 12th to 15th segments.
Notosetae ..		Two kinds:—(i) a stout series with grooved and serrated tips. (ii) a longer series with finely tapered curved tips, also denticled.	15. long, bristle-like; deeply set, fine hair-like, transparent, non-serrated. Only one kind.

Neurosetae	..	Fine, slender and of greenish hue; dorsally a few hooked, smooth, serratious setae, with a spur.	Few in number and comparatively short; tip curved, with striae.	Two kinds:—(i) hook or scythe-shaped (ii) club-shaped; both non-serratious.
Branchiae	..	Tuft like.	Commencing on the 3rd body segment and having the form of a dense arbuscles; bluish to feruginous in colour.	Clusters limited to the distant end of the notopodium; pale; simple in the 1st and end segments; found in all segments
Anus	..	———	Large, circular, embracing several segments at the posterior end of the body.	Terminal, surrounded by a pair of fan-like anal flaps.
Eyes	..	A single pair of marked eyes.	———	Two eyes on each side.
Distribution	..	Hulue, Maldives.	Bermuda, Atlantic, Indian and Pacific Oceans. Puri, Orissa, Andaman Sea. 112 fathoms. Nankauri Harbour.	Madras.

BIBLIOGRAPHY

1. Ehlers, E. "Report on the Annelids of the dredging expedition of the U.S. Coast Survey steamer 'Blake'—Florida Anneliden." Mem. Mus. Comp. Zool. Harvard College, 1888, Vol. XV.

2. Gravier, C.* "Contribution a' L'e' tude des Anne'lides Polyche'tes de la Mer Rouge." Nouve. Arch. du. Museum, Paris 1902, III. 147-152.

3. Hartman, Olga. "Annelida of the New England Coast." Bull. Amer. Mus. Nat. Hist. 1943-44, Vol. 82. 321.

4. Haswell, W.A. "On six new species of Annelids, belonging to the family Amphinomidae." Proc. Lin. Soc. N.S.W. 1878. 3. 341-347.

5. Horst, R. (a) "Contributions towards the knowledge of the Annelida Polychaeta. Pt. I. Amphinomidae." Notes. Ieyd. Mus. 1886 viii (2) 157-174. (b) "Polychaeta errantia of the 'Siboga' Expedition." Results. Exp. 'Siboga.' Monograph 24. 1912. 39-40.

6. McIntosh, W.C. "On Amphinome rostrata, Pallas, in the Atlantic and Indian Oceans." Ann. Mag. Nat. Hist. 1923. Series 9. 12. 90-94.

7. Monro, C.F.A. "Polychaetae belonging to the families Polynoidae, Eunicidae, Aphroditidae, and Amphinomidae. Collected by H.M.S. 'Alert' 1878-1882." Jour. Lin. Soc. Zool. London. 1924. 36. 37-77.

8. Potts, F.A. "Polychaetae of the Indian Ocean Pt. I. Amphinomidae." Trans. Lin. Soc. London. 1910. 2nd. Ser. XII. 355-371.

9. Treadwell, A.L. "The Polychaetous Annelids of Porto Rico." Bull. U.S. Fish. Comm. 1903. Pt. II. Vol. 20. 195.

10. Verrill, A.E. "Notice of recent additions to the marine invertebrates of the north-eastern coast, with descriptions of new genera and species and critical remarks on others. Part V, Annelida, Echinodermata, Hydroidia, Tunicata." Proc. U.S. Nat. Mus. 1885, Vol. 8. 424-448.

* Not referred to in the original.

KEY TO THE LETTERING

An.	: Anus	Car.	: Caruncle	Ph.	: Pharynx
An. Fl.	: Anal Flaps	Cb. S.	: Club-shaped Seta	Pp. Tt.	: Palpar Tentacles
Br.	: Branchiae			Sc. S.	: Scythe-shaped Setae
Bu.C.	: Buccal Cavity	E.	: Eyes		
		Int.	: Intestine		
		Mt.	: Mouth		
		Not. S.	: Notopodial Seta		

EXPLANATION OF THE FIGURES

Figure

1. The adult *in situ.*
2. The 8 segment stage.
3. The 18 segment stage.
4. Dorsal view of the anterior end of the adult 500.
5. Ventral view of the anterior end of the adult 500.
6. Ventral view of the posterior end of the adult, showing the position of the anal flaps × 600.
7. Notopodial Setae × 600.
8. Neuro setae, scythe-shaped × 600.
9. do. club-shaped × 600.
10. Ventral view of the 18 segment stage, showing the alimentary canal × 40.
11. Dorsal view of the 18 segment stage × 40.
12. Ventral view of the anterior end of the 8 segment stage, showing the transverse slit of the mouth and a part of the pharynx × 600.
13. Dorsal view of the 8 segment stage × 80.

THE DIGESTIVE SYSTEM OF *CARANX DJEDABA* (FORSK.) AND *TRICHIURUS HAUMELA* (FORSK.)

BY

S. MAHADEVAN, B.Sc.

(University Zoology Laboratory, Madras)

INTRODUCTION

A study of the available literature on the digestive system of fishes will not fail to impress one about the vast area covered by the previous workers. Nevertheless, when compared with our knowledge of the digestive tract of mammals, our understanding of the anatomy, the histology and of the functions of the different parts of the digestive tract of fishes is very incomplete.

The digestive system of the fishes received the attention of zoologists as early as in 1785, when Monro compared the structure and physiology of these in fishes with those of man and other vertebrates. Since then many have followed. But most of these workers give no description of the dentition, the gill-rakers, the buccal cavity and pharynx which provide the feeding mechanism suited to the type of diet of the fish. It will be useful if correlation of structure and function is extended to the detailed description of the morphology and the histology of the digestive tract. This kind of investigation was undertaken only by Al-Hussaini (1945, 1946, 1947 and 1949). Such a detailed study of the functional morphology and histology of the digestive tract, together with the feeding mechanism associated with their different types of diet would be of value if done on South Indian fishes. The present paper, the first of a series of investigations undertaken on the digestive system of fishes, deals with these of two carnivorous feeders viz., *Caranx djedaba* and *Trichiurus haumela.*

MATERIAL AND METHODS

It would have been ideal if all the fishes were examined as soon as caught. This not being possible due to the absence of a sea-going craft, the fishes were examined in the freshest possible condition. The importance of freshly preserved material for histological work cannot be overestimated, especially so in the case of fishes. Hence great care was taken in fixing the material.

Bouin's fluid was chosen for this purpose and was found to yield the best results. Other fixatives as Helly's and Duboscq's were also tried. Cedar wood oil was employed for clearing purposes and the usual method of paraffin embedding was followed. Wherever necessary decalcification was done with two per cent nitric acid alcohol of Boiling's modification of Bouin's fluid was tried which gave fairly-good result as it fixes as well as decalcifies the material. Heidenhein's Iron haemotoxylin, Delafield's and Ehrlich's haemotoxylin, Mallory's triple stain, especially for sections through the stomach and the intestinal regions, were the principal stains used. Mucicarmine, Picroindigo carmine and Picronigrosin were also used. Before Mallory's triple stain, a mordant of Hg Cl_2 in 2% acetic acid was used. For purposes of displaying the mucus cells, Hoyer's Thionin was found preferable to carmine stains in permanent preparation. Where granular cells are present, the different parts of the digestive tract were fixed in Helly's fluid for 18 to 24 hours, followed afterwards by washing in running water from 24 hours and dehydrating it gradually to 70% alcohol. Sections were cut 9μ thick and stained in Mallory's triple stain.

THE DIGESTIVE SYSTEM OF *CARANX DJEDABA* (FORSK)

Diet

Stomach contents from a number of fish examined revealed a truly carnivorous diet. Making allowances for the varying quantity of food found in a digested condition, the undigested matter when examined shows 56% crustaceans, 35% fishes and 9% other matter.

Gross Anatomy

This carnivorous feeder chases prawns, sepia and smaller fishes on the surface of the sea and opening its wide mouth and protruding its lips, captures them. When the mouth is closed the teeth interlock and prevent the escape of the prey. The gape of jaws is about 1·1 cms. in a fish measuring about 14 cms. long. The lips are supported by premaxilla and mandible. The upper lip is extended forwards by the action of *M. Geniohyoideu* and M. Sternohyoideus while the lower lip and the jaw, owing to the hyostylic suspension, are set in motion by ligaments. The closing of the jaw is effected by *Adductor mandibulae,* a complex muscle lying immediately below the skin in the cheek region.

On each jaw, a row of villiform teeth is present while vomer and palate also bear two or three rows. But the dentition in general is very weak. Each tooth is small and its tip pointed. Its base is

embedded in bone. The teeth are closely arranged and curved backwards. This arrangement of the teeth is suggestive of the fact that they are not used so much for biting as for preventing the prey captured from escaping out of the mouth. When the mouth is closed the teeth on the lower jaw interlock with those of the upper jaw, effectively imprisoning the prey. It was noticed that the upper jaw is shorter than the lower jaw so that the mouth opening is directed upwards. This feature is seen in fishes mainly feeding on the surface of the sea. While the protrusibility of the mouth increases the linear range of food capture as well as in grabbing the prey, the dentition prevents the escape of prey. Both these features efficiently aid the fish in securing the prey.

The mouth opening leads on into the buccal cavity. The anterior boundary of the buccal cavity is marked by the jaws and the posterior boundary by the first gill arches. The buccal cavity is covered by a white buccal membrane which is thrown into a set of longitudinal folds which are visible to the naked eye, especially so between the orbits of the eyes and along the sides. The buccal membrane shows no definite demarcation where it passes into the pharyngeal region. The floor of the buccal cavity accommodates the rudimentary tongue which is spatulate, attached anteriorly by a stout membrane to the floor of the buccal cavity; internally it is supported by the basihyal. The tongue is thus primitive, as in the case of other teleosteans.

The buccal cavity narrows down posteriorly to pass into the pharyngeal cavity. Four gills hang down on each side of the pharyngeal region. The gill-rakers of the anterior row of the first pair of gill arches are conspicuously developed. Those of the posterior row of the same arches and succeeding arches are rather rudimentary (Fig. 3). The rakers are coarse and short and hence cannot collect fine food particles. Such a type of gill-rakers was described by Suyehiro ('37) in *Gadus macrocephalus*. On the roof of the pharynx the pharyngobranchials of the 2nd, 3rd and the 4th arches are fused and are studded with small and villiform teeth which are similar to those of the jaws. In the floor of the pharynx similar teeth are disposed on a triangular plate formed by the completely coalesced inferiopharyngeals (Fig. 2). These villiform teeth help the fish in quieting and pressing the prey before they reach the oesophagus. Posteriorly, the pharynx becomes narrower and gradually attain a cylindrical form merging into the oesophagus.

The oesophagus is a short, stout, muscular tube connecting the pharynx with the stomach. The point of union of the pharyngeal and the oesophageal portions can be determined by a close inspec-

tion of the gross anatomy and by the occurrence of deep and close mucosal folds inside the oesophageal tube. The diameter of the oesophagus in a dextro-sinistral axis is 1·3 cms. and in a dorso-ventral axis about 0·8 cm. These figures represent the averages of measurements taken from the anterior portion the oesophagus. Nearer the stomach it measures 0·9 cm. in vertical and 0·5 cm. in the horizontal plane. The oesophageal wall insensibly merges into that of the stomach. On cutting open the wall of the stomach, longitudinal folds of varying depths and width between them are observed. The folds are clearly seen when fishes which have starved prior to dissection were examined.

The stomach is of the 'caecal' type (Fig. 1). Starting as a narrow bag it dilates to nearly twice the diameter and ends in a blind caecum. From the right side of this stomach extends the pyloric diverticulum which is thick-walled and which leads into the intestine. The pyloric pouch is also called the pyloric stomach incontradistinction to the rest of the stomach which is called the cardiac stomach. As the pyloric stomach tapers, the musculature of the wall increases so much in thickness that it obliterates the diameter of the lumen inside and forms a sort of pyloric sphincter. This pyloric stomach, when cut open, shows thick longitudinal folds similar to those seen in the cardiac stomach. In fact the folds are direct continuation of the folds of the cardiac wall. The caecal type of stomach suggests that it acts as a reservoir of food material. The pyloric sphincter on the other hand, with the help of its strong musculature, triturates the food before it enters the intestine. The tip of the stomach leads into the intestine. There was no valve between the intestine and the pyloric stomach though Dawes ('29) described a well developed valve in *Pleuronectes platessa.*

The intestine begins on the right side and almost immediately coils downwards to pass off into another coil before becoming straight and running backwards. This coiled portion of the intestine receives, anteriorly, the bile duct in the region of what may be called the duodenum. Opening by small pores into the duodenum are a number of thin, cylindrical, small caecae — the pyloric caecae (Fig. 1). These caecae are arranged in a 'rosette' pattern (Rahimullah '45). There were 16 pyloric caecae in the fish examined.

The intestine is fairly uniform in diameter and the wall is thin till it reaches the hind end. The entire tube measures about 6·5 cms. in a fish 13·5 cms. long. Probably the carnivorous diet of the fish does not need a long intestine. The hinder end or the region

just proximal to the anal outlet is bulging and the wall is thick. This is the rectal region. At the junction of the thick-walled rectum and the intestine, an intestinorectal valve is easily made out. This valve is a flap-like outgrowth from the wall and allows the material to pass from the intestine into the rectum. Such a type of valve was noted by Blake ('30) *in Prionotus carolinus* and by Al-Hussaini ('45, '46, '47), *in Scarus, Mulloides* and *Atherina.* The rectum tapers towards the anus and opens out through the small anal pore which is situated at the anterior third of the body length of the fish.

The gall-bladder is seen embedded in the liver mass and of bluish green colour containing bile. From this, the bile duct proceeds and finally opens into the duodenum. The pancreas is seen in the form of a thin tissue covered with blood vessels and is embedded in the liver mass and in the arms of the duodenum, sending a small duct which joins the bile duct before it opens into the duodenum. The fact that the duodenal intestine is receiving the bile and the pancreatic ducts into its lumen, is suggestive of the difference in the digestive function of the duodenum from the rest of the intestine.

Histology

(a) *Buccal cavity*: Histologically the buccal cavity is divided in to Mucosa (consisting of mucus epithelium, the basement membrane and the stratum compactum) and Submucosa. A striking feature of the buccal cavity is the presence of longitudinal folds and papillary structures both of the roof and of the exposed surface of the rudimentary tongue, appearing as cones with slightly bulged out middle portions, in a transverse section (Fig. 4).

Mucosa: The mucus epithelium is made up of undifferentiated epithelial cells, mucus cells and taste-buds. The epithelium of the stratified type with 10 to 12 layers of cells and much folded longitudinally (Fig. 5). The basal cells are columnar in nature with one of their tips pointed or spherical. Each cell possesses a large nucleus which fills about half of the cell and shows a distinct chromatin network. The nucleus is spherical or slightly oval, situated near the basal half. The layers above the basal ones are made up of cells which are mostly irregular in shape. The nuclei of these cells are round filling up most of the cell and stain lightly with haemotoxylin and eosin. The topmost layer of cells show a tendency to flatten out. The nuclei of these cells are likewise elliptical and stain heavily. Above these flattened cells are seen, in some sections cells which are also flattened and lack the full,

distinct nuclei of the underlying layers. Probably these are dead cells.

Mucus cells are present superficially in the epithelium though their number is restricted in the whole of the buccal mucosa. They are of the simple type and measure about 22μ in length. The cells are round and their nuclei are situated at the concave surface of the cell and hence flattened and their tips drawn out. The cells stain characteristically with thionin, showing a red coloration and reticulate structure inside the cell. The mucus cells open out into the buccal cavity by small pores.

The taste-buds are not as abundant as has been noticed in other fishes. They (the taste-buds) are located over the papillary structures projecting into the epithelium. These papillary structures are outpushings of the submucosa below. The tips of some of these papillae bear taste-buds which are spheroidal in shape (Fig. 5).Each bud measures 25μ in length, 15μ in width. The sides of the taste-buds are convex and the base concave. The exposed extremity is sunk in a pit which is probably homologous to the gustatory pores seen in mammals. The taste-bud is composed of few cells which are slender, elongated and 'oscillating' with elliptical nuclei, situated more towards the base than near the centre. The chromatin network of the nuclei stain heavily. The base of the taste-bud is lined regularly by cells with flattened nuclei. Probably these cells are akin to those of the mammalian sustentacular cells which serve to cover the bud. If it is so, the taste buds-found here are highly organized structures and approach those of mammals. At the base of the taste-buds are seen blood capillaries and a few nerve fibres, suggesting the sensory function of the buds. The compactly arranged stratified epithelium, the presence of mucus cells and the high organization of the taste buds all suggest the efficiency of the buccal cavity in helping the process of swallowing the food and in the process of preliminary digestion.

The entire epithelium is supported below by a membrane which is very thin, wavy in outline and staining uniformly due to the matrix being distributed uniformly. This is the basement membrane. Below this membrane is the stratum compactum which is also wavy and comparatively thicker than the epithelium. The fibres of the stratum compactum are closely arranged and stain deep blue with Mallory's. The stratum compactum as well as the basement membrane follow the contour of the epithelium and hence look folded.

Submucosa: This is made up of connective tissue fibres and is areolar in nature. The meshes of the tissue immediately below the stratum compactum are coarse and narrow while further below they are thin and broad. The entire tissue is well vascularized and innervated. There are also a few connective tissue nuclei strewn about in the meshes.

(b) *Pharynx*: The wall of the pharynx consists of three tunics viz., Mucosa, Submucosa and Muscularis. Many workers, notably Rogick ('31) and Curry ('39) distinguished an anterior and a posterior pharynx. In *Caranx* there is not enough justification for such a division, since the tunics constituting it are uniform throughout. When sections of both pharyngeal roof and floor were examined there is found a change in the nature of the epithelial folds. The crypts are narrow where the folds of the roof and floor, anterior to the pharyngeal teeth, are broad and deep. In the region of the pharyngeal teeth the folds are more shallow and broad making the crypts also shallow. However, posterior to the teeth the folds become deep again.

1. *Mucosa*: This consists of stratified epithelium like that of the buccal cavity and is supported by the basement membrane and the stratum compactum beneath. The stratified epithelium consists of only six or seven cell layers. The basal layer of columnar cells is covered by small cells in such a crowded state that it is difficult to make out the outlines of the cells of the particular layers. Their nuclei are prominent. The remaining two or three layers are marked by the development of large mucus-secreting cells. In regions where there are no such mucus cells or taste-buds, the uppermost cells of the mucosa show a tendency to flatten out. The mucus-secreting cells in the pharyngeal epithelium increase in number posteriorly. They are larger than before and saccular with round nuclei found basally. The reticulate effect, due to the presence of mucus inside the cells, is distinctly seen in transverse sections stained with Thionin. Taste-buds are lesser in number than the buccal cavity. Where present, they are found on the crests of the longitudinal folds at the tip of the papillae, formed of the evaginations of the connective tissue below, as in the case of the buccal cavity. The taste-buds disappear posteriorly whereas the mucus cells show the maximum development. Such an abundance of mucus cells was noted by Dawes ('29) in *Pleuronectes* and by Al-Hussaini ('47) in *Atherina*. The basement membrane is distinctly visible together with the stratum compactum adhering to it below. The stratum compactum is thinner in the floor than on the roof and is built of fibres which are very wavy in outline.

2. *Submucosa*: This is built up of connective tissue which is richer in blood vessals than the submucosa of the buccal cavity. But it is reduced in area. It is areolar in nature where it outpushes to form the papillary structures bearing taste-buds. There are few muscle fibres invading the submucosa even extending into the papillary projections. These muscle fibres belong to the muscularis below.

3. *Muscularis*: The muscularis is an additional tissue in the pharyngeal wall. It is not well demarcated from the submucosa, especially in the floor of the pharyngeal wall and runs in all directions. All the muscle fibres on the roof of the pharynx run parallel to the epithelium and they are of the striated variety. There is no trace of longitudinal muscle fibres at all anywhere. The well developed muscularis on the roof is suggestive of its function in assisting the dorsal cushions, bearing the villiform teeth, to work against similar teeth in the floor thus cutting or injuring the prey.

(c) *Oesophagus*: Part of the oesophagus lies anterior to the body cavity and the rest lies in the cavity and hence the first part is built up of three layers — Mucosa, Submucosa and the Muscularis — while the hinder part of the wall is built up of an additional serous coat. The longitudinal folds of the pharyngeal wall become deep and well developed in the oesophageal mucosa, there being 9 or 10 primary folds which branch into secondary folds, thus increasing the digestive surface (Fig. 6).

(1) *Mucosa*: The mucosa is made up of stratified epithelium of two or three layers near the pharyngeal wall, whereas posterior to it, it is made up of a single layer of cells. This stratified epithelium in the anterior region is lined by numerous mucus-secreting cells which are elongate in shape, measuring about 25·6μ in length by 6·3μ at its broadest place. The cells are rounded at the base and narrowed towards the lumen and open into it by small pores. The nuclei are compressed and situated basally where it is embedded in a scanty amount of cytoplasm. The typical columnar epithelium of the oesophageal wall is seen only posteriorly where it is composed of a single layer of short, cylindrical cells which measure 32μ in length by 8μ in width (Fig. 7). The mucus cells decrease in number as the oesophageal epithelium nears the gastric epithelium, and finally disappear. Taste-buds are completely absent from the oesophageal wall — a feature noted by all other workers especially, Al-Hussaini ('45, '46, '47), Rogick ('31) and Sarbahi ('40). Migratory leucocytes are found scattered here and there in the epithelium. They are smaller than the nuclei of the columnar cells and stain deeply with haemotoxylin and eosin.

Though a basement membrane is found supporting the epithelium, a stratum compactum is absent.

2. *Tunica propria*: This is built up of loose areolar connective tissue fibres, richly vascularized, supporting the primary and secondary folds.

3. *Submucosa*: This can hardly be distinguished from the tunica propria, except that in it are found scattered muscle fibres.

4. *Muscularis*: This consists of two layers — an outer circular layer and an inner longitudinal layer, both of them formed of striated muscle fibres. The inner longitudinal muscle fibres are not regularly arranged but are strewn in the meshes of the tunica propria. The outer circular muscle fibres are extremely thick and are responsible for the thickness of the oesophageal wall, especially anteriorly. This may be an adaptation to prevent the regurgitation of food from the stomach into the oesophagus and is also suggestive of the considerable distention it is capable of. The presence of two muscle layers of striated fibres is noteworthy. It may be observed here that Purser ('31) found, in *Calamoichthys*, only unstriated longitudinal fibres and considered it similar to that of the amphibians.

5. *Serosa*: This is composed of the pavement epithelium with flattened cells and centrally placed, deeply staining nuclei.

(d) *Stomach*: The stomach can be divided into the cardiac and the pyloric parts, histologically also. The longitudinal folds of the oesophageal region are continued into the stomach. But here the folds are so high and broad that when the stomach is empty they almost obliterate the lumen. There are mainly 9 or 10 primary longitudinal folds with occasional secondary folds as well.

Cardiac stomach: This is made up of the following coats: — Mucosa (superficial epithelium and glandular epithelium), Tunica propria, Submucosa, Muscularis and Serosa (Fig. 8), (Ph.m. 1).

1. *Mucosa*: Covering the folds of the mucosa is the columnar epithelium (Fig. 9). The columnar cells are closely arranged, slender at the base and broader at the apex measuring 3μ by 6μ at the free end in width and about 50μ to 70μ in length. The primary folds which measure about 850μ in height and 760μ in width are separated from the adjacent ones by deep, narrow crypts. These gastric crypts increase the digestive surface. The columnar cells lining the valleys are taller than those of the oesophageal wall, with basally situated nuclei. There is no 'Top plate' covering the free border of the columnar cells. But mucus covers the entire epithe-

lium as may be seen from sections. The mucus might have been secreted by columnar epithelium itself or by the oesophageal mucus cells. Since the columnar cells do not give any positive reaction to Mucicarmine or Thionin, this mucus should have been secreted by the oesophageal cells which give the reaction.

The glandular epithelium is considerably thick and is suggestive of vigorous secretory capacity and makes the mucosa appear dense. The glands are all of the tubular type, long and broad. In a section the glands appear irregular in outline. Adjacent glands are separated by means of thin connective tissue septa which make the glands appear as compartments (Fig. 9). The connective tissue septa, stained uniformly blue by Mallory's triple stain, are continuous with the connective tissue of the secondary folds and the primary folds. The septal tissue is well vascularized. Each gastric gland is polygonal in outline and made up of six to twelve cells which also appear polygonal in transverse section (Fig. 10). The nuclei are spherical and are situated away from the lumen of the gland. The protoplasm of the cells show granular bodies, closely arranged. The cells of the gastric glands are not differentiated into two types — the parietal and the central as in mammals. Edinger (1877) has shown this and has been confirmed by all successors working on the gastric glands of fishes. Probably the glandular cells observed in this case are mainly zymin-producing ones, the granules being zymogen granules. The glands open into the gastric crypts directly or indirectly through the columnar epithelium below. No differentiation of neck cells was noticed at the place where glands open into the crypts directly, as was noted by Gulland (1898), in Scottish salmon, Dawes ('29) in *Pleuronectes* and Al-Hussaini ('46) in *Mulloides*. But, as in the present case, neither Greene ('12) nor Blake ('30) found any such neck cells.

2. *Tunica propria*: This supports the primary folds and extends its loose areolar tissue fibres in between the gastric glands, as already stated, thus helping to bind the glands together.

3. *Submucosa*: This is also built up of an areolar connective tissue where the meshes become close and dense near the muscularis. The submucosa and the tunica propria where they meet, pass into each other insensibly.

4. *Muscularis*: The muscularis is built up of two distinct layers, an outer longitudinal and an inner circular layer. Both the muscle fibres are of the unstriated type. The circular layer is twice as thick as the longitudinal and measures 142μ.

5. *Serosa*: The serosa is considerably thicker than that of the oesophagus due to the subserous connective tissue supporting a distinct layer of flat cells with eliptical nuclei.

Pyloric stomach: The pyloric stomach differs from the cardiac stomach in that the gastric glands are completely absent from its mucus epithelium while its muscularis is far thickened. The Muscosa folds (950μ tall) are slender and more in number than in the cardiac stomach (Ph.m. 2). The wall of the pyloric stomach consists of the same tunics as that of the cardiac stomach.

1. *Mucosa*: The cylindrical cells of the columnar epithelium are smaller than those of the cardiac stomach and measures 25μ long by 5μ broad. These cells are also covered by mucus out-side. There is no glandular epithelium and this feature determines this region from the cardiac.

2. *Tunica propria*: Like the cardiac stomach wall, this layer supports the folds.

3. *Submucosa*: Similar to that of the cardiac wall.

4. *Muscularis*: The outer longitudinal muscle layer is thin measuring only 65μ. In between the longitudinal and circular fibres small blood vessels are held by connective tissue.

5. *Serosa*: Similar to that of cardiac stomach.

No special valve could be dedected between the pyloric stomach and the intestine but the folds just thrusting in towards the intestine, may function as such. There are no multicellular glands found guarding the orifice as was noted by Berndt ('38) in *Anguilla*.

(e) *Intestine*: The intestine is characterised by the presence of unbranched, tall, slender, longitudinal folds which enclose narrow crypts between them. A few transverse folds also occur. The intestine is made up of the following tunics:—Mucosa, Tunica propria, Stratum granulosum, Stratum compactum, Muscularis and Serosa (Ph.m. 3), (Fig. 11).

1. *Mucosa*: The mucus epithelium is typically columnar and the cells of the mucosa are of only two or three types. The commonest type is of the tall columnar kind. The other type of cells are, mucus-secreting goblet cells, wandering leucocytes as well as some granular cells which invade the epithelium (Fig. 13). The columnar epithelium cells are high and measure about 43 to 50μ in length by 2·2μ in breadth. The nuclei are oval in shape and show a distinct chromatin net work. A thin laminal border at the

free end of the columnar cells indicates the presence of the top plate which is striated (Fig. 13). The striations are at right angles to the epithelial cells. The plate measures 1·5μ thick and is continuous along the border of the entire epithelium except where interrupted by goblet cells which open into the lumen of the intestine.

The mucoid secretion is derived from the next most abundent type of cells. These secretory cells have a broad 'head' and a narrow 'tail' and the body of a typical goblet cell. These goblet cells open into the intestinal lumen by wide pores. Each cell measures about 35μ to 50μ long by 8μ broad, at the broadest portion of the cell. In the 'tail' is an oval or spherical nucleus located in a mass of cytoplasm (Fig. 13). The goblet cells are numerous especially at the middle and posterior regions of the intestinal wall. They are lesser in the anterior and in the rectal regions. The goblet cells are the fewest in the anal region. They show no localization, appearing both on the crests and crypts of the folds. Transitional stages between the columnar cells and the goblet cells were noticed; the intermediate cells being round in outline with mucine inside and oval nucleus at the base. The head of the goblet cells as well as the nucleus show variation in structure and position. The 'head' may be round, elongate or dumb-bell shaped. The nuclei are found either beneath the 'head' or may be situated basally in the 'tail' (Fig. 11).

During active digestion the intestinal columnar cells showed clear vacuole-like structures. A similar phenomenon was noted by Rogick ('31) and was subject of controversy. She considered these clear vacuoles to be early stages in the accumulation of mucus within but investigation of McVay and Kaan ('40) on *Carassius auratus* threw considerable doubts on the interpretation. In addition to the specific mucus reaction of these cells no intermediate cells between these cells and the typical goblet cells could be found. Moreover, such vacuoles were not found in the oesophagus during active digestion. This coupled with the findings of Dawes ('29) who noted that the resting cells contained a darkly staining mass in the centre but which disappeared during active digestion, leaving below a pale staining border in each cell, would suggest a possible relationship between the appearings of the vacuole and the presence of food in the digestion tract.

Wandering cells, mentioned by Greene ('12) as presumably of the laucocyte type, were noted and their presence is shown by their nuclei staining distinctly and darkly than the oval nuclei of

the columnar cells. Some other granular cells, resembling those beneath the mucosa (vide infra), are seen to invade the epithelium.

2. *Tunica propria*: This portion of the sub epithelial connective tissue supporting the columnar epithelium is composed of fibres arranged loosely. This areolar tissue has scattered through its fibrous strands small oval nuclei, wandering leucocytes and granular cells described as invading the epithelium.

3. * *Stratum granulosum*: Immediately next to the tunica propria, towards the musculature is a layer of peculiar loose cells. (Fig. 12) They seem as it were suspended in the areolar tissue itself. The cells are large and of various shapes — oval, spherical or irregular. The cytoplasm contains numerous granules and therefore stain vividly. Greene ('12) and Blake ('36) found similar cells in the intestinal wall. Greene ('12) finds them in between the circular muscle fibres and the stratum compactum. But here the location differs, as stated above.

4. *Stratum compactum*: The presence of the stratum compactum is another interesting feature. (Ph. m. 4). This is thin, measuring 4μ thick and forms a clear and wavy band with its constituents staining uniformly. This is brought about as a blue belt when stained with Mallorys stain. Probably this stratum helps to support the epithelium. The appearance of this, however, is surprising since it was discontinued after the pharynx. Above this stratum and below the muscularis there are seen very narrow fibrous tissues, probably of the submucosa.

5. *Muscularis*: The muscularis consists of two layers, a thicker, inner layer of circular muscle fibres and a thinner, outer longitudinal fibres. Both are of the unstriated type. Between these layers small blood vessels are seen. The thickness of the circular muscle layer is not uniform throughout and varies from 50μ to 78μ. It is thin anteriorly and thicker near rectum. The longitudinal muscle layer is thinner and measures 20μ thick, in the maximum. Subserous connective tissue is found to bind these longitudinal fibres here and there.

6. *Serosa*: The serosa is composed of cuboidal cells, single layered and supported by sub-serous connective tissue which extends down into the longitudinal layer to interdigitate among the fibres forming interstices.

* The term stratum granulosum is retained although cells belonging to this layer are found wandering in the tunica propria and in the mucosa.

Rectum: The junction of the intestine and rectum is separated by an ileorectal valve and is made up of connective tissue fibres, derived from the tunica propria. The wall of the rectum is composed of the same layers as the intestine; the main differences observed being that the muscularis uniformly measures 105μ thick and that the longitudinal folds of the rectum are stouter and deeper. The number of goblet cells is greater in the middle part than in the distal or the proximal portions of the rectum. The tunica propria is highly vascular. Blake ('30), Young and Fox ('36), Purser ('31) Sarbahi ('40) as well as Al-Hussaini ('45, '46, '47) distinguished rectum by abundant goblet and granular cells. This is not true in *Caranx* as the goblet cells are definitely fewer than in the intestinal region and disappear near the anal outlet, a feature noted by Dawes ('29) also. The only way to distinguish a rectal region is the strong musculature, as was noted by Nusbaum-Hilarowicz ('16), besides the ileorectal partition valve.

Pyloric caecae or Intestinal caecae: The plyoric caecae resemble the intestinal region, from which they diverticulate, in their fundamental structure. Greene ('12) notes the same feature. Rahimulla ('45) in his elaborate work on the pyloric caecae concludes that the structure of these caecae is similar to that part of the intestine from which they diverticulate and suggests the name 'intestinal appendage' instead of the misleading term pyloric caecae. This seems acceptable since the caecae do not arise from the pyloric stomach nor do they resemble it. On the other hand, as is seen, the structure resembles the duodenal intestine.

1. *Mucosa*: The epithelium is similar to that described for the intestine adjoining the caecae. (Fig. 15) The common type is of the columnar cells. Goblet cells are seen here and there. No ciliated columnar cells were observed as was noted by Rahimulla ('45) in *Mullus barbatus*.

2. *Tunica propria*: Compared with its extent in the intestine this is more restricted in pyloric caecae though more richly vasculated.

3. *Stratum granulosum*.

4. *Stratum compactum*: These are similar to that of the intestine.

5. *Muscularis*: This is thinner than the intestinal wall measuring on the whole about 30 to 40μ, the circular layer alone measuring 20μ.

6. *Serosa*: It is difficult to make out the serosa as it is very thin.

THE DIGESTIVE SYSTEM OF *TRICHIURUS HAUMELA* (FORSK.)

Diet

This fish, popularly called the ' ribbon-fish ', occurs off the coast of Madras abundantly, especially during the months of October, November and December. Devanesan and Chidambaram (48) give an account of the fish and its food. Its diet is predominantly carnivorous and the fish is a voracious feeder, swallowing economically important fishes as *Sardinella fimbriata, Engraulis, Stolephorus,* Grunters, Horse meckerels, Silver-bellies, *Kowall thoracata* Croackers, fish larvae and also prawns excepting *penaeus* and *squilla* species. Both the diet and the structure of the gut as a whole show that these ribbon fishes are carnivorous.

Gross Anatomy

The gape of the mouth in the open state is large and wide (4·3 cms. in a fish measuring 54 cms.) formed solely by the premaxilla and to some extent by the posterior end of the maxilla and a part of the articular at the angle of the mouth. The mouth on the whole is not protrusible even to the slightest degree and the mechanism of opening and closing the mouth is the same as that of a fish with non-protrusible mouth (Eaton '35).

The dentition is like that of a typical predator, best suited for seizing and biting the fishes and prawns which form its diet. Teeth are found on both the jaws and are better developed than the other fishes described in the present paper. In the upper jaw they are found on the premaxillary bone, (about 10 to 12 in number) there being only a single row of teeth which are strong, short, conical and curved. Anteriorly, in the premaxilla, are two large, sharp teeth bent inwards presenting a fang-like or caniniform appearance. There are two similar but smaller teeth above the symphysis of the lower jaw (and in advance of the end of the snout when the mouth is closed) (Fig. 16) and the lateral ones are lesser in size than those in the upper jaw. The teeth are all firmly ankylosed with the bones. Except for the caniniform teeth all the teeth are alike. The dentition is thus suited for prehension and biting. There are no palatine and vomerine teeth.

The buccal cavity is broad anteriorly and narrows down posteriorly, towards the pharynx. The roof of the buccal cavity is lined by a whitish membrane, longitudinally folded and divided into two by a longitudinal furrow along the middle line. This mem-

brane merges with the membrane of the pharynx where the longitudinal folds become less discernible to the naked eye. The floor of the buccal cavity is less extensive than the roof. The rudimentary tongue is situated medially and is long with pointed free end, internally supported by the cartilagenous basihyal. The surface of the tongue is flat while the edges are convex. Posteriorly, where the Geniohyoideus and Basibranchials enter, the tongue is thinner. The buccal cavity was found to be always slippery due to the copious mass of mucus secreted.

The pharynx may be taken as extending from the first gill arch and closing with last gill arch. The pharynx communicates outside through the wide gill slits. The first pair of gill arches have two rows of gill rakers of which only one row i.e. close to the operculum is well developed. Each of these gill-rakers is broad at the base and whip-like at the tip (Fig. 17). The succeeding gill arches show two rows of rakers on each arch but they are just small prominences. The reduced condition of the gill-rakers, the absence of a well developed pharyngeal set of teeth, the secretion of mucus in the buccal cavity and the pharynx as well as the dentition, all proclaim the predatory character of the fish. The stomach when cut open showed that the piscine or crustacean prey injured but not masticated by the teeth. The anterior ends of all the prey are directed towards the oesophagus showing that the fish has chased and swallowed the prey from behind.

The oesophagus is a cylindrical and short tube leading into the stomach. Internally the oesophagus shows complex longitudinal folds which lead into those of the stomach. The folds are such that in a starved fish they almost occlude the lumen leaving only a small space in the middle. That the oesophagus should be capable of enormous distension may be inferred from the size of the prey found in the stomach.

The shape of the stomach is peculiar in being produced backwards into a long tubular cardiac portion on the right side of the anterior end of which is attached the pyloric part. (Fig. 18). The wall of the stomach is thick, muscular and highly distensible. The distensible caecal stomach is suited to serve as a receptacle for the large quantities of food swallowed by this voracious feeder. The pyloric stomach arises from the ventral side and is narrow thick walled tubes directed towards the duodenum.

No valve was observed guarding the entrance of the pyloric orifice into the intestine. The intestine is a very short tube. This reduction in length of the intestine is also noted in the other carni-

vorous feeder *Caranx*. The anterior portion of the intestine receives the pyloric caecae. The caecae are cylindrical and finger-like diverticula opening by separate pores. Among these pores is the opening of the bile duct, though this cannot be discerned with the naked eye. The wall of the intestine as well as that of the caecae is transparent so that the longitudinal folds inside are visible. The anal opening occurs immediately in front of the anal fin and is oval in outline.

Histology

(a) *Buccal cavity*: The wall of the buccal cavity can be divided into the Mucosa (consisting of the mucus epithelium of the stratified nature, the basement membrane and supported by the far thicker stratum compactum) and Submucosa.

(1) *Mucosa*: This is of the usual stratified type composed of only few layers of cells. The epithelium is noteworthy in being uniform without longitudinal folds and not having taste-buds. The buccal epithelium of *Pleuronectes* is also reported by Dawes ('29) as free of taste-buds. The absence of the taste-buds implies the lack of any gustatory sense in this voracious feeder. The epithelium is also noteworthy in having numerous mucus-secreting cells, especially on the roof of the buccal cavity (Fig. 19). These cells differ from the other cells of the epithelium which are polygonal or irregular in shape and have a central nucleus. The cells are very closely arranged without any space in between. The basal layer consists of similar short columnar cells as in the case of *Caranx*. Their nuclei are found to occupy the lower half of the cell and they are elongated or slightly oval and stain lightly, with haemotoxylin. Some cells are distorted due to the intervening mucus secreting-cells being distributed superficially. These cells are large in size measuring 25μ in diameter. Their nuclei stain deeply and are elongate situated at the bottom of the mucus cells. The mucus cells are made turgid due to the accumulation of mucus inside and once the mucus is discharged into the buccal cavity through the wide mucus pore, these cells collapse. The abundance of mucus cells is suggestive of the copious amount of mucus secreted which is necessary for lubricating the large amount of food swallowed. The basement membrane stains clearly due to the matrix being distributed uniformly. Below the basement membrane is the stratum compactum made up of bands of closely packed fibres. The area occupied by these fibres is double that of the mucosa. No trace of muscle fibres could be noticed in the sections that are taken from this region.

The rudimentary tongue is made up of the same layers except that the mucus epithelium consists of only two or three cell layers. The mucus cells as they peel off after secreting mucus are replaced by other younger cells cut off from below. This cell proliferation is made possible by the plentiful supply of blood to these layers.

Pharynx: The essential histological features are exactly similar to those of the buccal cavity.

(b) *Oesophagus*: The oesphageas wall consists of mucosa, submucosa, muscularis and a serosa (posteriorly). Of these four layers the mucosa and submucosa form the complex longitudinal folds of the oesophageal wall. These folds display an arborizing system and increase the absorptive or secretive surface. The anterior region in epithelium is composed of simple mucus-secreting cells resembling those of the buccal cavity. In the middle region columnar cells and goblet cells occur while in the posterior region columnar cells and simple mucus cells are observed. A large mucus cell measures about 18μ along its long axis by 3μ across. The goblet cells are few in number and measure 29μ along its length by 2μ in breadth. The nuclei are round and situated just below the 'head' of the cells and stain lightly. The columnar cells measure 27μ in length by 7μ in breadth. (Fig. 20)

The entire oesophageal epithelium is supported by a thin casement which is wavy. Below this are the connective tissue fibres loosely arranged to form the *tunica propria.* The vascularization of this layer is particularly noticeable. This fact coupled with the increase of surface caused by the tall and slender folds suggest greater capacity for absorption.

Muscularis: The musculature of the oesophagus is composed only of striated circular muscle fibres, 95μ thick. The muscle fibres are not closely set and are seen to be occasionally invading the tunica propria. There is no evidence of longitudinal muscle fibres, much less of a separate layer of longitudinal muscles. Al-Hussaini ('45, '46) noted a circular layer of fibres in *Mulloides* and *Scarus* and found longitudinal fibres in the subepithelial connective tissue layer. *Serosa* is indistinguishable from the subserous tissue.

(c) *Stomach*: (i) *The cardiac stomach*: The cardiac stomach consists of similar layers as in other fishes described.

Mucosa: The mucosa is exceedingly thick, especially near the fundic stomach where the glands which compose it are very deep wide. The superficial epithelium is made up of columnar cells. The cells along tips of the folds are usually taller than those lining

the crypts. Besides these columnar cells, mucus cells which are not ordinarily met with in the stomach of fishes are found (Ph.m.) These simple mucus-secreting cells are of unique shape. Broad towards the lumen, the body becomes narrower in the middle and vesicular towards the base. It is here that the spherical, lightly staining nuclei are situated. (Fig. 21) Such types of mucus cells have not been met with in other fishes and its occurrence in the stomach is unique.

The glands are of the tubular type and arranged in such a way that they generally form tubes based at right angles to the surface, separated from one another by connective tissue septa. Each gland is long and broad. The cut ends of the glands, as is evident from transverse section, are usually many sided. The glands are formed of six to thirty cells. (Fig. 22) The cells are probably the peptic cells as will be seen from their cytoplasm being granular. Their nuclei are spherical and stain lightly. The granules, probably zymogen, are conspicuous especially when the fish was starved prior to sectioning. The glands open outside through a narrow canal at the bottom of the gastric crypts. This opening is guarded by cells which are cubical in shape and have spherical nuclei. They stain heavily and their cytoplasm is not granular. In *Pleuronectes* Dawes ('29) found neck cells staining deeply with Mucicarmine and considered them as mucoid cells, scattered among the so called peptic cells of the mammalian fundic glands. Al-Hussaini ('46) mentions these cells in *Mulloides,* but observes that they do not react similarly to Mucicarmine as in the Plaice and concludes that their mucus-secreting activity is 'doubtful'. These cells in *Trichiurus* also do not react positively with mucicarmine coinciding with the observation on *Mulloides.*

Tunica propria : This connective tissue is of loose areolar kind. It also sends strands in between the gastric glands serving as a packing tissue. There is an outer layer of connective tissue below the muscularis. The meshes of this submucosal layer are close.

Muscularis : The gastric muscular coats are made up of the external unstriated longitudinal muscle layer and the thicker, inner, unstriated circular muscle layer. The circular muscle layer is thrice as thick as longitudinal layer which though very thin, is uniform throughout.

Serosa : This is composed of a single layer of flat cells with deeply staining elliptical nuclei.

(1) *Pyloric stomach* : Though the wall is composed of the same layers yet differs from the cardiac stomach in the glands being

completely absent and the muscular layers being thicker. Mucosal folds are taller 800μ high and 450μ broad, and more in number than in the cardiac stomach.

Mucosa: The columnar cells lining the folds are typically cylindrical, measuring 26μ long and 3μ broad.

Tunica propria and Submucosa are similar to that of the cardiac stomach.

Muscularis: This is made up of the same two muscle layers with the circular layer alone attaining a thickness of 815μ whereas the longitudinal is nine times thinner. Longitudinal sections taken at the junction of the pyloric wall and duodenum do not reveal the presence of valvular mechanism; nor where any multicellular glands observed as was described by Berndt ('38).

Intestines: mucosa, tunica propria, muscularis, and serosa form the wall of the intestine. The mucosal folds are mainly longitudinal but also transverse in some places. The folds are very long and profuse near the duodenal region. The folds become fewer and more regularly arranged when they reach the middle intestines.

Mucosa: This is made up of columnar epithelium differentiated into two types — cylindrical and mucus-secreting cells. (Fig. 23) The cylindrical cells measure 21μ long and 4μ broad. At the crypts of the folds they become shorter and measure 17μ in length and 4μ in breadth. The nuclei stain lightly showing distinct chromatin network. Though near the duodenum they are abundant. The maximum number of cells, however, occur only in the posterior intestinal region; for every cylindrical cell there are two such cells. The mucus cells show localization only in the duodenal region, occurring on the sides of the folds. Those cells occurring on the crests of the folds in the posterior intestines are goblet-shaped. Probably the transformation of mucus cells into goblet cells proceeds from the crypts of the fold towards the crests. Wandering leucocytes also are seen here. There are some granular cells scattered interstially. They stain bright red with Eosin, they are eccentrically placed and unlobed.

Tunica propria: This appears to support the epithelium, in the absence of the basement membrane which is not easily discerned, and is made up of loosely arranged fibres. The granular cells, described in the epithelium are abundantly seen here, especially near the anal opening. These granular cells show greater

concentration near the muscularis though they do not form a distinct layer.

Muscularis: The usual two layers of unstriated fibres, uniformly thick throughout, constitute the muscularis. The circular fibres alone are twice as thick as the longitudinal.

Serosa: This is composed of the pavement epithelium with deeply staining nuclei.

Rectum: The region of the proximal end of the intestines is not clearly marked except by the large number of goblet cells characteristic of the rectuma and described by Purser ('31) in *Calamolchthys*. The valve or the thick musculature noted by Al-Hussaini ('45, '46, '47) in *Scarus, Mulloides* and *Antherina* are not in evidence.

Pyloric caecae or *Intestinal caecae*: The similarity between the pyloric caecae and the intestinal region has been noticed throughout the present study and the previous workers like green ('12), Rahimulla ('45) and Al-Hussaini ('45, '46, '47) have shown that the close similarity between the organs may support the view they are really intestinal appendages and not pyloric appendages as the name may suggest. The nature of the mucosal folds, the distribution of the goblet cells and the constituent layers are similar to what are found in the duodenal region. The tunica propria is highly vasculated than the intestinal wall.

Summary

1. The anatomy and histology of the digestive system of two carnivorous feeders, of which one is predaceous, have been studied in detail. Several adaptive features in the dentition, nature of the mouth, the structure of the gill-rakers, are described in detail.

2. Peculiar structures such as the occurrence of mucus cells in the gastric epithelium of *Trichiurus*, the stratum compactum and the stratum granulosum in the intestine of *Caranx* are noted.

3. Taste-buds resembling those of mammals are present in the buccal and pharyngeal mucosa of *Caranx*.

4. Histologically the pharynx is not differentiated in *Trichiurus*.

5. The fundamental structure of the pyloric caecae resembles that of the anterior part of the intestines from which they diverticulate.

ACKNOWLEDGMENT

I wish to express my indebtedness to Dr. C. P. Gnanamuthu, M.A., D.Sc., F.Z.S., Director, University Zoology Laboratory, for his helpful criticism and guidance.

EXPLANATION OF FIGURES

1. Outline drawing of the alimentary tract.
2. Dorsal and ventral pharyngeal plates.
3. Gill-rakers of the first and the second gill arches.
4. Transverse section of the buccal wall.
5. Buccal epithelium (highly magnified).
6. Cross section of the oesophageal wall.
7. Oesophageal epithelium (highly magnified).
8. Transverse section through the cardiac stomach.
9. Gastric epithelium (highly magnified).
10. Gastric gland (highly magnified).
11. Transverse section of the intestinal wall.
12. Transverse section of the intestinal wall (magnified).
13. Intestinal epithelium (highly magnified).
14. Goblet cells from the intestinal epithelium.
15. Epithelium of the pyloric caecae (highly magnified).
16. Lateral view of the jaws of *Trichiurus*.
17. Gill-rakers of the first gill arch.
18. Outline drawing of the alimentary tract.
19. Transverse section of the buccal wall.
20. Oesophageal epithelium (highly magnified).
21. Gastric epithelium (highly magnified).
22. Gastric gland (highly magnified).
23. Intestine transversely sectioned.

KEY TO LETTERING

a.	..	Anus.
are. t.	..	Areolar tissue.
b.m.	..	Basement membrane.
b.v.	..	Blood vessel.
bl. c.	..	Blood capillaries.
bl. cor.	..	Blood corpuscles.
can. t.	..	Caniniform teeth.
c.m.	..	Circular muscle.
c.t.	..	Connective tissue.
cre.	..	Crests.
cry.	..	Crypts.
c.t.n.	..	Connective tissue nuclei.
col. c.	..	Columnar cell.
cush.	..	Cushion.
duo.	..	Duodenum.
g.fi.	..	Gill fillaments.
g.r.	..	Gill-rakers.
gl.c.	..	Glandular cell.
gl.e.	..	Glandular epithelium.

gl.o. .. Glandular opening
gob. c. .. Goblet cell.
gr. c. .. Granular cell.
gus. c. .. Gustatory cell.
int. .. Intestine.
irr. c. .. Irregular cells.
l.m. .. Longitudinal muscle.
leu. .. Leucocytes.
lum. .. Lumen.
mu. .. Mucosa.
mu. c. .. Mucus cell.
nu. .. Nucleus.
oes. .. Oesophagus.
oes. o. .. Oesophageal opening.
p.f. .. Primary folds.
py. .. Pyloric stomach.
py. c. .. Pyloric caecae.
s.f. .. Secondary folds.
s.m. .. Submucosa.
ser. .. Serosa.
st. car. .. Cardiac stomach.
str. com. .. Stratum compactum.
str. epi. .. Stratified epithelium.
str. gra. .. Stratum granulosum.
su. e. .. Superficial epithelium.
ta. b. .. Taste-bud.
t. p. .. Top plate.
tri. p. .. Triangular plate.
tu. p. .. Tunica propria.
vit. p. .. Villiform teeth.

REFERENCES

1. Al-Hussaini, A.H. (1945). The anatomy and histology of the alimentary tract of the coral-feeding fish *Scarus sordius*. Bull. Inst. d'Egypte, Vol. 27.

2. Al-Hussaini, A.H. (1946). The anatomy and histology of the alimentary tract of the bottom-feeder, *Mulloides auriflamma* (Forsk.). J. Morph. Vol. 78.

3. Al-Hussaini, A.H. (1947). The anatomy and histology of the alimentary tract of the plankton-feeder, *Atherina forskali* (Rupp.). J. Morph. Vol. 80.

4. Al-Hussaini, A.H. (1949). On the functional morphology of the alimentary tract of some fish in relation to difference in their feeding habits. Q.J.M.S., Vol. 82.

5. Berndt, O. (1938). Morphologie und Histologie des Rumpf darmes von *Anguilla fluviatilis* und die veranderungen desselben im individualzyklus.

6. Blake, I.H. (1930). Studies on the comparative histology of the digestive tube of certain teleost fishes I. A predaceous fish, the sea-bass (*Centrepristes striatus*). J. Morph. Vol. 50.

7. Blake, I.H. (1936). Studies on the comparative histology of the digestive tube of certain teleost fishes III. A bottom-feeding fish the searobin (*Prionotus carolinus*). J. Morph. Vol. 60.

8. Curry, E. (1939). The histology of the digestive tube of the carp (*Cyprinus carpio communis*). J. Morph. Vol. 65.

9. Dawes, B. (1929). The histology of the alimentary tract of the plaice (*Pleuronectes platessa*). Q.J.M.S., Vol. 73.

10. Devanesan and Chidambaram. (1948) Common Food fishes of the Madras Presidency. (Publication of the Dept. of Industries and Commerce).

11. Eaton, T.H. (1935). Evolution of upper jaw mechanism in teleost fishes. J. Morph, Vol. 58.

12. Edinger, L. (1877). Uber die schleimhaut des Fischdarmes nebest Bemerkungen zur phylogenese der Drusendes Darmrohres. Arch. F. Mikros. Anat. Vol. 13.

13. Greene, C.W. (1912). Anatomy and histology of the alimentary tract of the king salmon. Bull. Bur. Fish. Wash. Vol. 32.

14. Gulland, G.L. (1898). The minute structure of the digestive tract of the salmon and the changes which occur in it in fresh water. Anat. Rnz. Vol. 14.

15. Manro, H. (1785). The structure and physiology of fishes explained and compared with those of man and other animals. Edinburgh.

16. Nusbaum-Hilarowicz, J. (1928). Sur la structure bu canal digestif chez gastrostemus bairdii (Gull et Ryder). Bull. Inst. Ocean. Monaco No. 315.

17. Purser, G. L. (1931). *Calamoichthys calabaricus*, J. A. Smith, Part I. The alimentary and respiratory systems. Trans. Royal. Soc. Edn. Vol. 54.

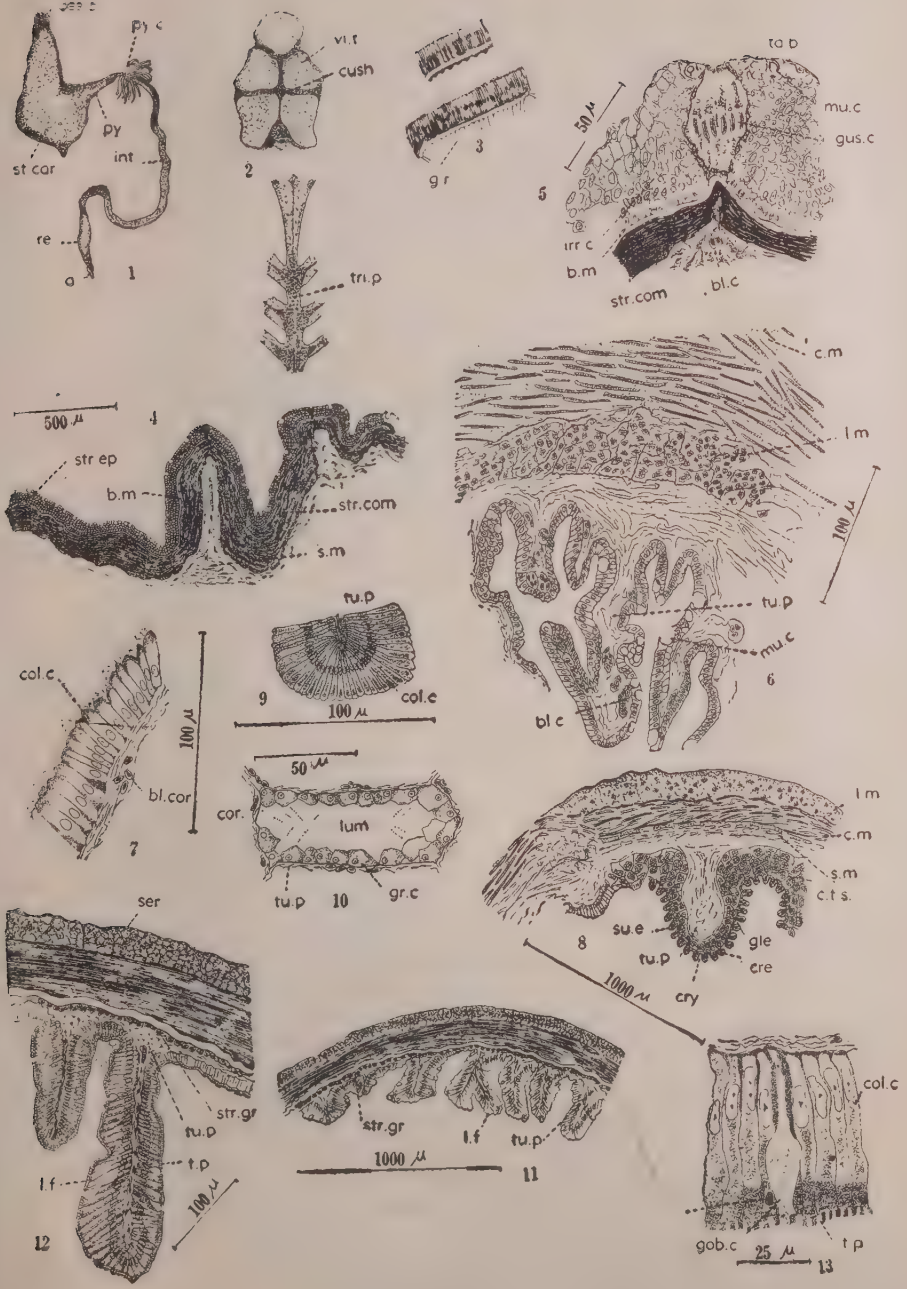
18. Rahimulla. M. (1945). A comparative study of the morphology, histology and probable functions of the pyloric caecae in Indian fishes together with a discussion on their homology. Proc. Ind. Acad. Sci. Sec. B. Vol. 21.

19. Rogick, M.D. (1931). Studies on the comparative histology of the digestive tract of certain teleost fishes II. A Minnow (*Compostoma anomalum*). J. Morph. Vol. 52.

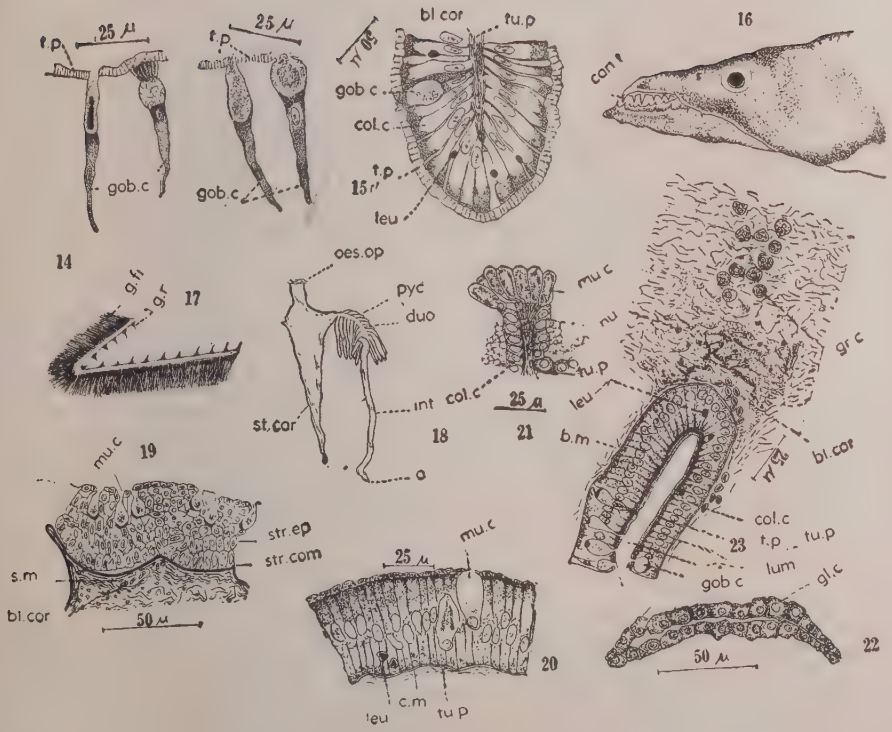
20. Sarbahi, D.S. (1940). The alimentary canal of *Labeo rohita* (Hamilton). J. Asiat. Soc. Bengal. Vol. 5. No. 2.

21. Suyehiro. Y. (1934). Studies on the digestive system and feeding habit of the important fishes of the North Pacific I The cods, *Gadus macrocephalus. Tilesus* and *Theragra chalcogramma* (*pallas*). Bull. Jap. Soc. Fish. Tokyo. Vol. 3.

22. Young, H.T., and Fox, D.L. (1936). The structure and function of the gut in surf-perches (Embiotocidae) with reference to their carotenoid metabolism. Biol. Bull. Vol. 71.


py c
py
int
st car
re
a
1
vi.r
cush
2
3
g r
tri.p
ta b
mu.c
gus.c
50 μ
irr c
b.m
str.com
bl.c
5
500 μ
4
str ep
b.m
str.com
s.m
c.m
l.m
100 μ
tu.p
mu.c
6
bl c
tu.p
col.c
9
100 μ
col.c
100 μ
bl.cor
7
50 μ
cor.
lum
tu.p
10
gr.c
l.m
c.m
s.m
c.t.s.
su.e
gle
tu.p
cre
8
1000 μ
cry
ser
str.gr
tu.p
t.p
l.f
100 μ
12
str.gr
l.f
tu.p
1000 μ
11
col.c
gob.c
t.p
25 μ
13

Figs. 1—13


t.p
25 μ
gob.c
14
bl.cor
tu.p
gob c
col.c
t.p
teu
16
can
g.fi
g.r
17
oes.op
pyc
duo
int
st.car
a
18
mu.c
nu
tu.p
col.c
25 μ
21
leu
gr.c
b.m
bl.cor
col.c
23
t.p
tu.p
lum
gob c
gl.c
22
50 μ
19
mu.c
str.ep
str.com
s.m
bl.cor
50 μ
25 μ
mu.c
20
teu
c.m
tu.p

Figs. 14—23

FAT CONTENTS OF THE MUSCLES OF THE INDIAN HERRING, *PELLONA HOEVENII* (BLEEKER)

BY

K. V. Sekharan

University Zoology Laboratory, Madras

Introduction

In a previous paper (1949), the author had shown that the muscle fats of the rainbow sardine, *Dussumieria acuta* undergo periodic changes in quantity in relation to feeding and maturity. In this paper, the fats in the muscles of another fish, *Pellona hoevenii*, in different periods of the year are studied from the same point of view.

Material and Methods

Pellona hoevenii ("Kuthuvai" in Tamil) is the commonest of all Indian herrings in Madras and is an important food-fish of the area. In its diet list crustacea occupy the first rank with small teleosts coming only second in importance. And between August and December, when the coastal waters around Madras are rich in plankton, the fish feed and grow rapidly and (as Moses 1922, observes) are landed in large numbers from November to January. The greater part of the process of maturation is also effected in the local coastal waters, but in the collections made no spawning specimens were found apparently because the fish move away from the area for reproduction. This probably explains the decline in numbers which though recognisable after January, is more remarkable after March.

Weekly samples of the fish were collected from August 1948 to May 1949 and also from August 1949 to May 1950. They totalled 511 individuals, an average of about 50 fish a month, but because of the abundance of the fish between August and January, the samples recorded in these months far exceeded this average, though in the other months attempts were made to collect as many as possible.

Methods

A. Fat determination. For estimating the fat content of the muscles, essentially the same methods as were described with regard to *D. acuta* (1949) were adopted — viz: (1) Wilson's method (1939) of staining slices (measuring 0·5 to 1 cm. in thickness) for fat; (2) Measuring the median stained region in all slices and adjusting this area to that of a standard slice and (3) Extraction of fat chemically from individual fish. But unlike formerly, the median stained regions in all the slices were measured by a net-micrometer under the same magnification (6 × 3) and the standardised slice measured 100 mm. × 50 mm. Samples for chemical analysis were prepared following Bruce's method (1924) and the tissues were gently ground up with chemically pure sand (Lewkowitsch 1913) before extracting the fats first with redistilled rectified spirit and then with ether.

B. Determination of maturity stages of the fish:

As the fat contents of any fish may vary in relation to the degree of maturity, it was necessary to ascertain the condition of the gonads. For determining the stages of maturity of the fish the standards defined by the International Council for the Exploration of the Sea, and quoted by Lovern and Wood (1937) were adopted. Though these definitions were made principally with regard to fishes of the European waters they were observed to apply equally to the fish dealt with in the present study. Hence these standards which are also adopted by the Government Fisheries Department were used. The data obtained by weighing the gonads in different fishes confirm the applicability of the above standards of maturity to the fishes studied.

C. Feeding habits of the fish:

In order to correlate the fat content of the fish to the food consumed, stomach from samples consisting of two or more individuals were opened and the total volume of the stomach contents measured. The contents were then separated into: (a) crustacea; (b) teleostei and (c) the rest including digested matter; the volumes of these respective items were also measured and expressed as percentages of the total volume of the stomach contents. To find the rate of feeding the total volume of the stomach contents was divided by the number of fish included in the samples.

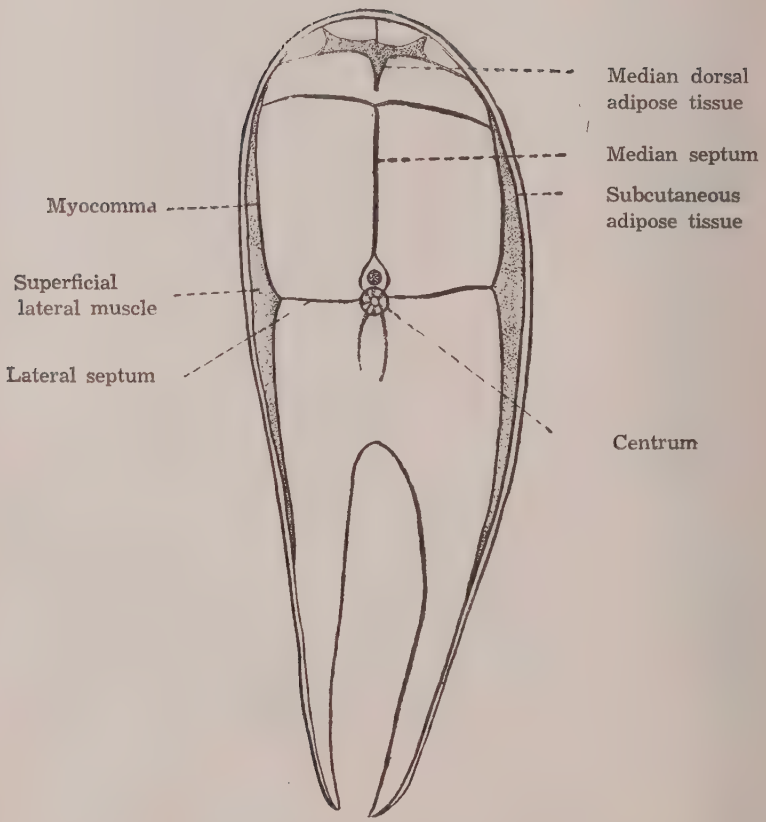


Fig. 1. A slice of *P. hoevenii* to show the distribution of fat and adipose tissue. (Fat areas shaded).

Distribution of fat and adipose tissue in and around the muscles

As in *D. acuta*, slices taken from the region just behind the pectoral fin gave the best picture of fat when stained. When such a slice is examined, the greatest concentration of adipose tissue is seen to be in the form of a T in the upper third of the slice, with the vertical arm accommodated between the deep lateral muscles and the horizontal arm joined to this in its middle (Fig. 1). This depot of fat as seen in a stained slice is remarkable for the definite outline of the area it covers when compared to it the other coloured regions. Hence, as in *D. acuta*, only this dorsal adipose tissue was measured by the net-micrometer, when determining the fatness of a fish by the method of calculation of fat-spread.

The superficial lateral muscles form a fat reservoir of only minor importance. Where the myocommata meet the skin a little adipose tissue is observed. In addition to this, adipose tissue is developed between the skin and lateral muscles, but the dorsal half of the slice is more striking for the amount of sub-cutaneous fat present than the ventral half. And in fish of the maximum fatness level, the underlying tissues seem to be separated altogether from the skin by a sheath of adipose tissue. (Fig. 1).

In the centrum of a moderately fat fish, usually seven coloured sectors are found to occur. And the arches of the vertebral column also usually reveal coloured patches around them.

As in the case of *D. acuta*, a comparative study of the extent of the stained regions in a number of slices (about 100) prepared from different samples, showed that individuals of the population could be arranged in eight fat degrees, with regard to the amount of fat contained in and around their muscles. Later samples also justified this division and these degrees are defined in the Table I and illustrated in Fig. 2a-h. The first column gives the stained regions in slices from fish of the different fat degrees, the second column the corresponding area of the dorsal adipose tissue as measured from that slice and expressed in terms of a standard slice (100 mm. $\times$ 50 mm.), and the third column, the amount of fat in the muscles of a fish of that particular fat degree.

TABLE I

Stained regions in slices representing *Pellona* of different fat degrees, the area of the dorsal adipose tissue in a typical slice (100 mm. × 50 mm.) the amount of fat contained in fish of the different fat degrees.

Fat Degrees	Stained Regions	Fat Area	Fat %
1. Fig. 2a.			
	A. *Dorsal adipose tissue*: Only the horizontal arm appears.		
	B. *Superficial lateral muscles*: Not coloured; but myocommata in this region may be associated with some adipose tissue.	upto 60	upto 1·25
	C. *Sub-cutaneous adipose tissue*: Developed where the myocommata reach the skin.		
	D. *Centrum*: May have a few coloured sectors.		
2. Fig. 2b.			
	A Traces of the vertical arm appear especially in the lower part.	60 to 100	1·25 to 2
	B. May be coloured a little.		
	C. As before.		
	D. About seven coloured sectors.		
3. Fig. 2c.			
	A. The lateral branches of the horizontal arm are very thick in the region where they meet, so that together they give an appearance of two triangles joined together by their bases; the vertical arm being formed.		
	B. Coloured a little; the myocommata bounding these muscles at their thickest part appear as red lines.	100 to 140	2 to 2·75
	C. Between the skin and lateral muscle, appears as thick isolated dots.		
	D. As before.		
4. Fig. 2d.			
	A. The 'T' shape well seen.	140 to 180	2·75 to 3·5
	B. Coloured area increases.		
	C. The thickness of the dots increases.		
	D. As before.		
5. Fig. 2e.			
	A. The area of the adipose tissue increases.		
	B. Coloured area increases.	180 to 220	3·5 to 4·25
	C. The dots are joined by a thin line which extends about 2/3rds. of the way up from the middle part of the superficial lateral muscles.		
	D. As before.		

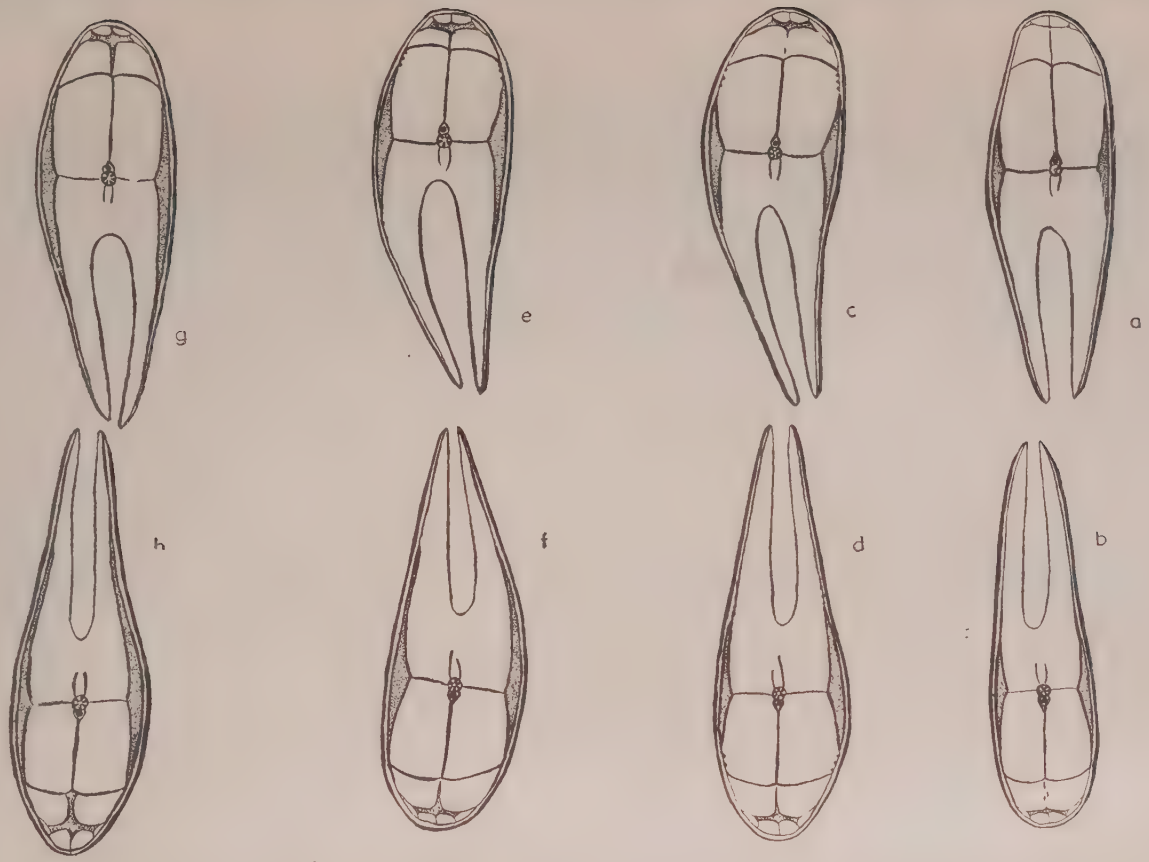


Fig. 2

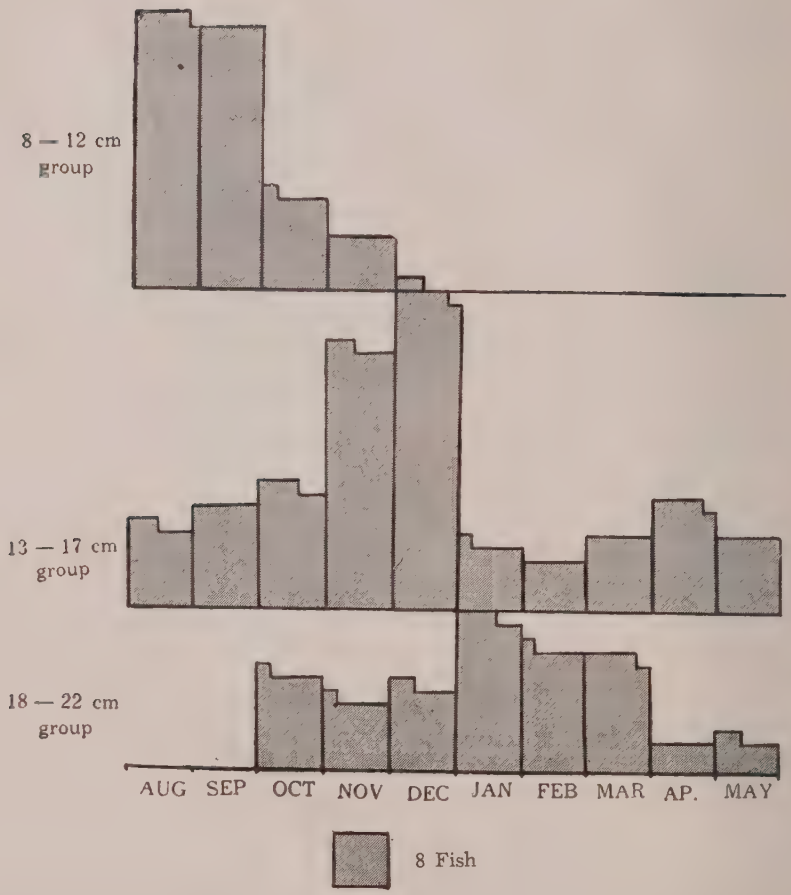


Fig. 3. The number of *P. hoevenii* of the three length-groups obtained in different months.

Fat Degrees	Stained Regions	Fat Area	Fat %
6. Fig. 2f.			
	A. Width increases.		
	B. Coloured upto about 2/3rds. of the way up from the thickest part.	220 to 260	4·25 to 5
	C. The line extends dorsally again.		
	D. As before.		
7. Fig. 2g.			
	A. Increases still more.		
	B. Colour extends upto about 2/3rds. of the way up.	260 to 300	5 to 5·75
	C. The red line beneath the skin extends upto the region where the tip of the horizontal arm of the dorsal adipose tissue touches the skin.		
	D. As before.		
8. Fig. 2h.			
	A. Maximum development.		
	B. As before.	300 to 350	5·75 to 7
	C. Thick layer of fat tissues encloses the underlying muscles.		
	D. As before.		

Length-groups and their fat values in different months :

The samples obtained from the Madras Beach varied between 8 cms. and 22 cms. in length. They were grouped arbitrarily into : (a) small ; (b) large and (c) very large fish, measuring 8-12 cms., 13-17 cms., and 18-22 cms., respectively. The small fish predominated the collections made in August and September. (Table II. Fig. 3). The large fish are available almost throughout the year, though as may be seen from Table II and Fig. 3, there is a decline in their strength after January. Fish measuring 18-22 cms. in length were first recorded in October, and they continued to occur in the commercial catches upto March, after which they were rare.

TABLE II

The number of individuals of the three length-groups of *Pellona hoevenii* obtained in different months.

Months	Length — groups		
	8-12 cms.	13-17 cms.	18-22 cms.
August ..	52	16	—
September ..	50	20	—
October ..	18	24	18
November ..	10	51	13
December ..	1	62	16
January ..	—	13	29
February ..	—	10	23
March ..	—	15	22
April ..	—	22	5
May ..	—	15	6
Total ..	131	248	132

The fat values of these three length groups, which together exhaust the length-range of the commercial landings, are recorded in Tables III, V and VII and represented in the form of percentage number in each fat degree in Figs. 4, 5 and 6 respectively.

(a) *Small size-group* (8-12 *cms.*): The figure for August show that over 90% of the samples obtained in this month were in degree 3 or below. 6% were in degree 4. But the September collection had only 56% in fat degrees 1 to 3, and the percentage number in degree 4 registered an increase upto 18%, the remaining 26% being in the higher fat degrees 5 to 8. As in the next two months. October and November, there was no fish in these higher fat degrees 7 and 8, it is reasonable to infer that these small fish, characterised by the high fat values are only exceptional. But a glance at the relative proportions of the other fat degrees reveals that on the whole the fish is fattest in October and November. Especially in the month of November about 70% of the sample were spread between degree 4 and 6 and 20% were seen to be in degree 3. In December only one fish in this group was obtained, and was omitted. Probably these small-sized fish measuring 8-12 cms. enter the next length groups (13-17 cms.) by October or November and hence their scarcity from December onwards.

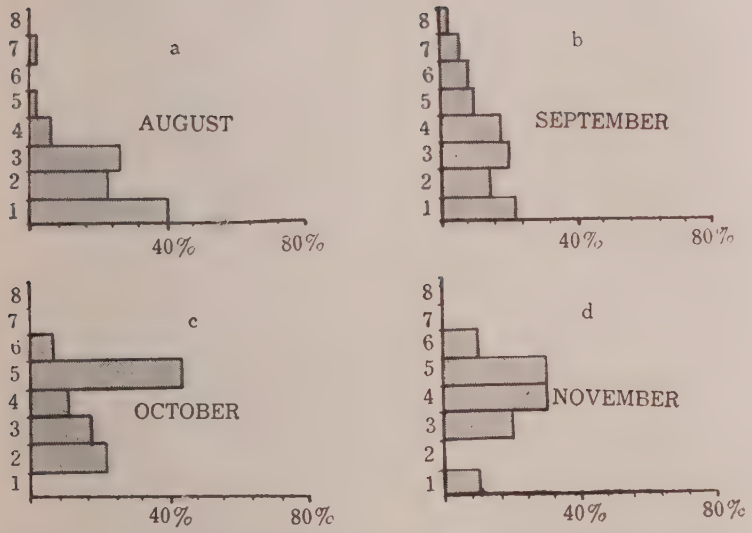


Fig. 4, a—d. The fat value of *P. hoevenii* (8-12 cm. group) in different months. (In the form of percentage number in each fat degree).

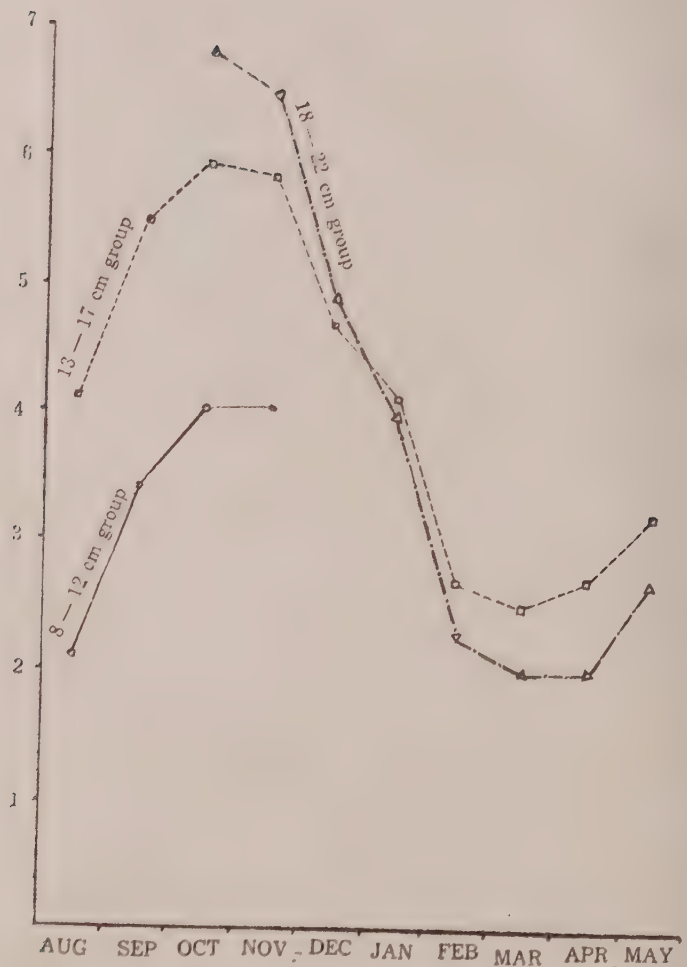


Fig. 7. The average fat value of the three length-groups of *P. hoevenii* in different months.

TABLE III

The fat value of *Pellona hoevenii* of the 8-12 cms. group in different months.

Months	Fat Degrees								Average
	1	2	3	4	5	6	7	8	
August ..	21	22	14	3	1	—	1	—	2·1
September ..	11	7	10	9	5	4	3	1	3·4
October ..	—	4	3	2	8	1	—	—	4·0
November ..	1	—	2	3	3	1	—	—	4·0
December ..	—	—	—	1	—	—	—	—	4·0

From Table III, the monthly mean fat degree of the fish of this length group can be calculated. The averages thus obtained are represented in Fig. 7. It shows that these fish become richer in fat from August onwards and that their maximum fatness is registered in the October — November period.

These small-sized fish do not mature in any part of the year. They feed entirely on crustacea which are taken in increasing amounts from August onwards. (Table IV).

The rate of feeding as measured by the volume of stomach contents also goes up from August. This probably accounts for the increased deposition of surplus fats in the muscles from August onwards.

TABLE IV

The average volume of food taken and the volumetric percentages of the different items of diet consumed by *Pellona hoevenii* of the length-group 8-12 cms. in different months.

Months	Average volume of food taken (in cubic centimetres).	Crustacea	Teleosts	The rest including digested matter.
August ..	0·3	53%	—	47%
September ..	0·3	52%	—	48%
October ..	0·4	61%	—	39%
November ..	0·4	60%	—	40%

Large size-group (13-17 *cms.*). Large fish reach their peak abundance between October and December and afterwards shrink

considerably in their numbers, probably because some of them join the next length group (18-22 cms). The fat value of these large fish in the various months are shown in Table V and also in the form of diagrams. (Fig. 5 a-j).

The diagram for August shows about half of the number examined in that month to be in degree 3 or below, but about 25% were included in the fat degrees 4 and 5 and the rest were accounted for by fat grades 6 and 7. The September sample contained 35% of the fish in degree 8. Though October shows a smaller percentage number in this highest fat degree, yet it does not indicate that the October fish was leaner, for it may be seen that 80% of the collection made in October were above degree 4, and the average is higher than in September. In November obviously the fish attains the maximum fatness, when about 47% were recorded in degree 8. The percentage number above degree 4 was about 71, but this drops to 60% in December, which therefore represents a decline in fatness. This decrease is more notable in January when only 39% were above degree 4 and about 54% of the sample varied between degrees 2 and 3. The March sample was obviously the leanest of the series for about 80% of the number of fish examined in that month were below degree 4.

But the April collection had only 73% spread between degrees 1 and 3. A slight increase in fatness was thus recognisable. And in May 47% were found to be above degree 3 and the rest in degree 3 or below indicating a partial recovery.

TABLE V

The fat value of *Pellona hoevenii* of the 13-17 cms. group in different months

Months	Fat Degrees								Average
	1	2	3	4	5	6	7	8	
August ..	1	2	5	1	3	2	2	—	4·1
September ..	3	—	2	1	3	2	2	7	5·5
October ..	—	1	1	3	5	5	3	6	5·9
November ..	5	6	1	3	6	2	4	24	5·8
December ..	11	3	3	8	9	12	9	7	4·7
January ..	—	3	4	1	2	1	1	1	4·1
February ..	2	4	1	1	2	—	—	—	2·7
March ..	6	3	3	1	—	2	—	—	2·5
April ..	7	7	2	1	3	1	1	—	2·7
May ..	5	2	1	2	3	1	1	—	3·2

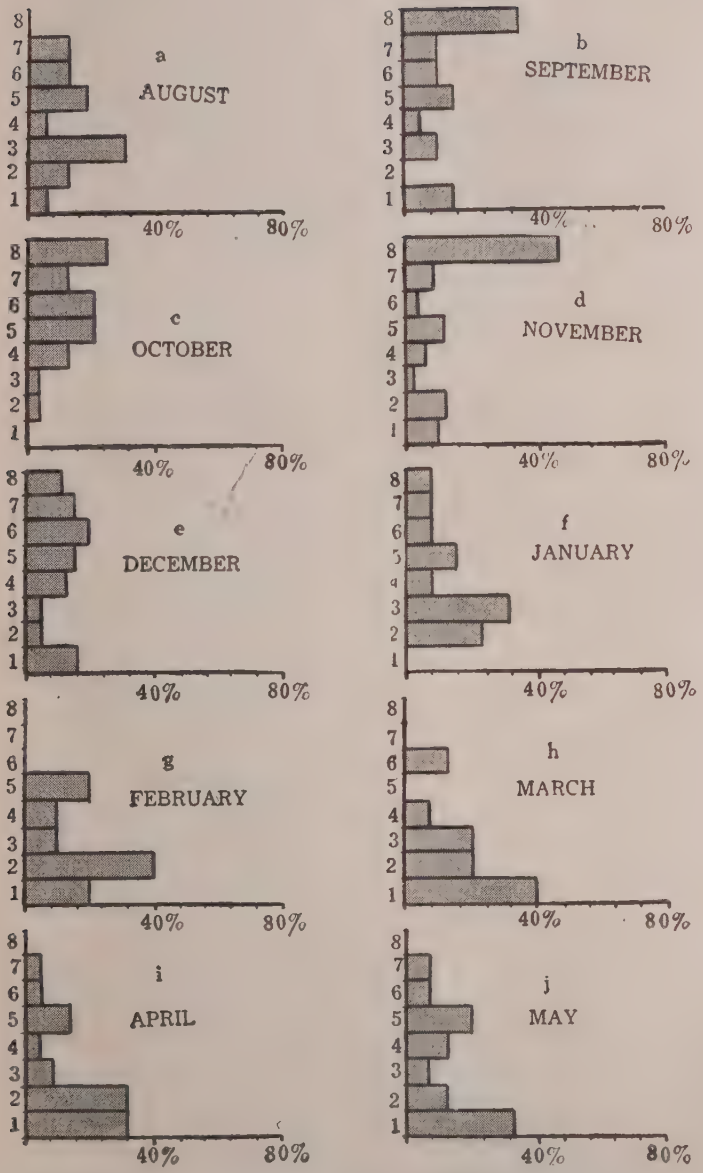


Fig. 5, a—j. The fat value of *P. hoevenii* (13-17 cm. group) in different months. (In the form of percentage number in each fat degree).

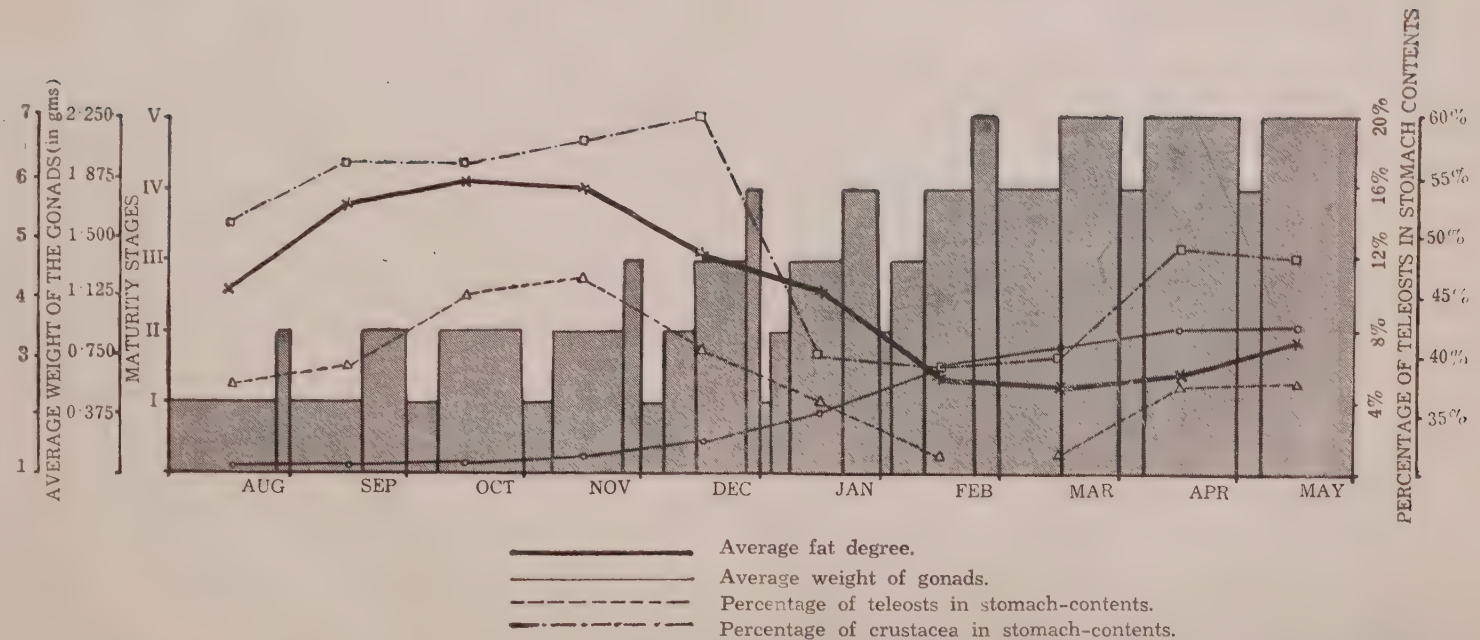


Fig. 8. Fat content, maturity and feeding (on Teleosts and Crustacea) in *P. hoevenii* of the 13-17 cm. group.

As before, it is possible to work out the average fat degree of this length group in every month. They are given in the Table V and Figs. 7 and 8. The graph maintains an upward trend from August to November, the maximum level being seen in October — November. The downward trend starts after November, and continues uninterrupted upto March. In April it rises a little and in May this rise representing an increase in the fat level of the fish is clearly brought out.

These periodic changes in the value of muscle fats seem to have some correlation to the changes in the feeding habits of the fish. As the Table VI shows, the fish keeps up a high rate of feeding from August to November and takes in crustacea in large numbers and teleosts in fairly moderate quantities. And this abviously enables the fish to deposit in its tissues surplus material in the form of fat which reach its peak value at this time.

But from December to March, the stomach of the fish reveals a steadily diminishing volume of teleosts present. Crustacea keep up their former level upto December, but fall afterwards until March; besides, at this time the fish does not appear to consume the same volume of food as before; it undoubtedly suffers a decrease and probably this lack of quality and quantity of diet seems to be a contributory factor towards bringing down the value of stored fat (Fig. 8). Yet the depletion in fat recorded is so heavy that it is very difficult to refer it solely to changes in feeding, especially if we note the extent of difference between the feeding data for this period and those for the previous period. And we are led to suspect the operation of another factor which results in greater expenditure of fat between December and March (Vide infra). In April there is an increase in the amount of crustacea and teleosts consumed, as well as in the rate of feeding; but in April the average fatness improves only very little though by May the increase in fat value is well recognisable.

It has been mentioned above that the fall in fat value requires a probable cause for greater expenditure. The process of maturation serves only to emphasise this. In the period August — November the fish of this length group are almost all immature (stages I and II), and so probably divert little fat for gonad growth (Table IX. Fig. 8). Absence of expenditure in this direction may help in the accumulation of fat. But from December onwards the gonads mature rapidly. Stages III and IV appear in December and January and Stage V in February and March (Table IX) while the average weight of the gonads increases at this time, and the fish is steadily

TABLE VI

The average volume of food taken and the volumetric percentages of the items of diet consumed by *P. hoevenii* of the 13-17 cms. group.

Months	Average volume of food taken (in cubic centimetres)	Crustacea	Teleosts	The rest including digested matter.
August ..	1·1	51%	5%	44%
September ..	1·4	56%	6%	38%
October ..	1·3	56%	10%	34%
November ..	1·4	58%	11%	31%
December ..	1·0	60%	7%	33%
January ..	0·7	40%	4%	56%
February ..	0·7	39%	1%	60%
March ..	0·6	40%	1%	59%
April ..	1·2	49%	5%	46%
May ..		48%	5%	47%

impoverished of fat. The fish reaches its minimum fat value in March. This shows that one of the important circumstances leading towards a greater expenditure may be the development of the gonads (Fig. 8). This gets further support from the fact that it is only in December and the succeeding months that the gonads advance to maturity Stage III and above, which are characterised by the appearance of fat globules in the cytoplasm of the egg, while formerly the ovaries were in Stages I or II, when the eggs do not reveal fat, at least demonstrable fat. And it is probable that fats diverted for deposition in gonads come at least partly, if not wholly, from the muscles.

In April most of the fish are in maturity Stage V, but the fat value does not decrease further. This is probably due to the loss of fat being partially compensated for by feeding (as stated above). But further maturation does not require expenditure of fats at least in the case of eggs (Milroy 1898) and as a consequence, the fat contents register an increase in May.

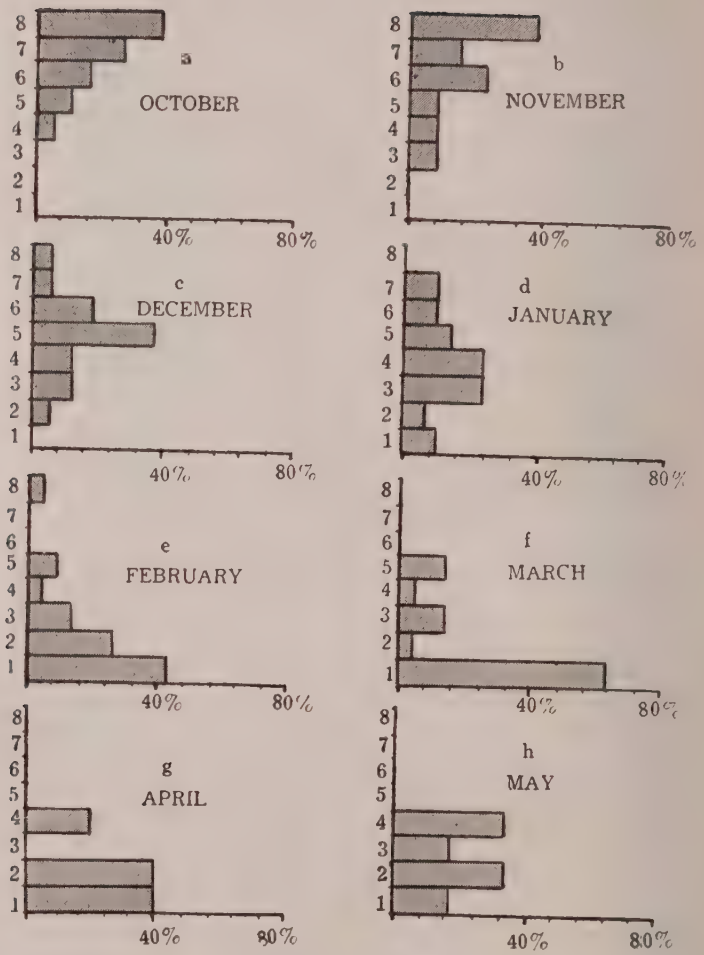


Fig. 6, a—h. The fat value of *P. hoevenii* (18-22 cm. group) in different months. (In the form of percentage number in each fat degree).

Very large-sized fish (18-22 *cms*): As was stated before, the very large-sized fish were available in large numbers from December to March and were rare thereafter. The fat records for this length-group are given in the Table VII and in Fig. 6 a-h.

The October sample had 67% of its number in degrees 7 and 8 while in November the number in these degrees decreases to 53% in October degree 3 was not represented, while it appears in November and accounted for 8% of the sample. The fish was therefore poorer in November, contrary to the condition observed in the 13-17 group which had its maximum fat content in the October — November period.

In December 57% of the fish were in degrees 5 and 6, with only 12% in higher degrees and the removal of fat from the muscles is continued upto March when nearly 70% of the fish were distributed between degrees 1 and 2 and the rest in degrees 3, 4 and 5. In April only 5 specimens could be collected and they showed no improvement, but the May sample, consisting of 6 individuals, had half of them in degrees 3 and 4 and the rest in 1 and 2. The fish was therefore slightly richer.

TABLE VII

The Fat value of *P. hoevenii* of the 18-22 cms. group in different months.

Months	Fat Degrees								Average
	1	2	3	4	5	6	7	8	
October ..	—	—	—	1	2	3	5	7	6·8
November ..	—	—	1	1	1	3	2	5	6·5
December ..	—	1	2	2	6	3	1	1	4·9
January ..	3	2	7	7	4	3	3	—	4·0
February ..	10	6	3	1	2	—	—	1	2·3
March ..	14	1	3	1	3	—	—	—	2·0
April ..	2	2	—	1	—	—	—	—	2·0
May ..	1	2	1	2	—	—	—	—	2·7

The average fat degree for each month is given in the Table VII and also in the Figs. 7 and 9.

The average for October is 6·8 but it falls to 6·5 in November. Thus the decline in fat starts earlier in this group compared to the fish of the previous size-group. The graph then undergoes a steep fall upto March — April, but goes up in May.

The data for feeding habits indicate that in October and November crustacea and teleosts are taken in large amounts, though of course, crustacea still maintain their predominance as was witnessed in the previous length-group (Table VIII). The volume of stomach contents is also highest for the year in these two months, yet the fatness level drops in November, suggesting increased expenditure due to other factors (Vide infra). From December upto March the intensity of feeding as well as the proportion of teleosts consumed falls, coinciding with the decrease in fat value (Fig. 9) Crustacean items in stomach do not diminish up to December, but they do not seem to be sufficient to compensate for the loss of fat. This shows that more than crustacean items, the teleostean constituents are important in the nutrition of the fish. But this decline from fat degree 6·8 to about 2·00 in March is too great to be satisfactorily accounted for only by the decline in the quality and quantity of food taken. (Vide infra). The data for feeding in April and May cannot be regarded as important, as only 11 individuals were examined in those two months, but as far as they go, they show an increase in the teleostean and crustacean percentages, together with an increase in the volume of stomach contents. Hence probably the rise in the value of fat in May.

TABLE VIII

The average volume of food taken and the volumetric percentages of the chief items of diet of *P. hoevenii* of the 18-22 cms. group in different months.

Months	Average volume of food taken (in cubic centimetres)	Crustacea	Teleosts	The rest including digested matter
October ..	1·5	52%	20%	28%
November ..	1·7	53%	16%	31%
December ..	1·0	57%	10%	33%
January ..	0·8	43%	8%	49%
February ..	0·8	40%	5%	55%
March ..	0·7	40%	3%	57%
April ..	1·1	52%	6%	42%
May ..	1·0	53%	7%	40%

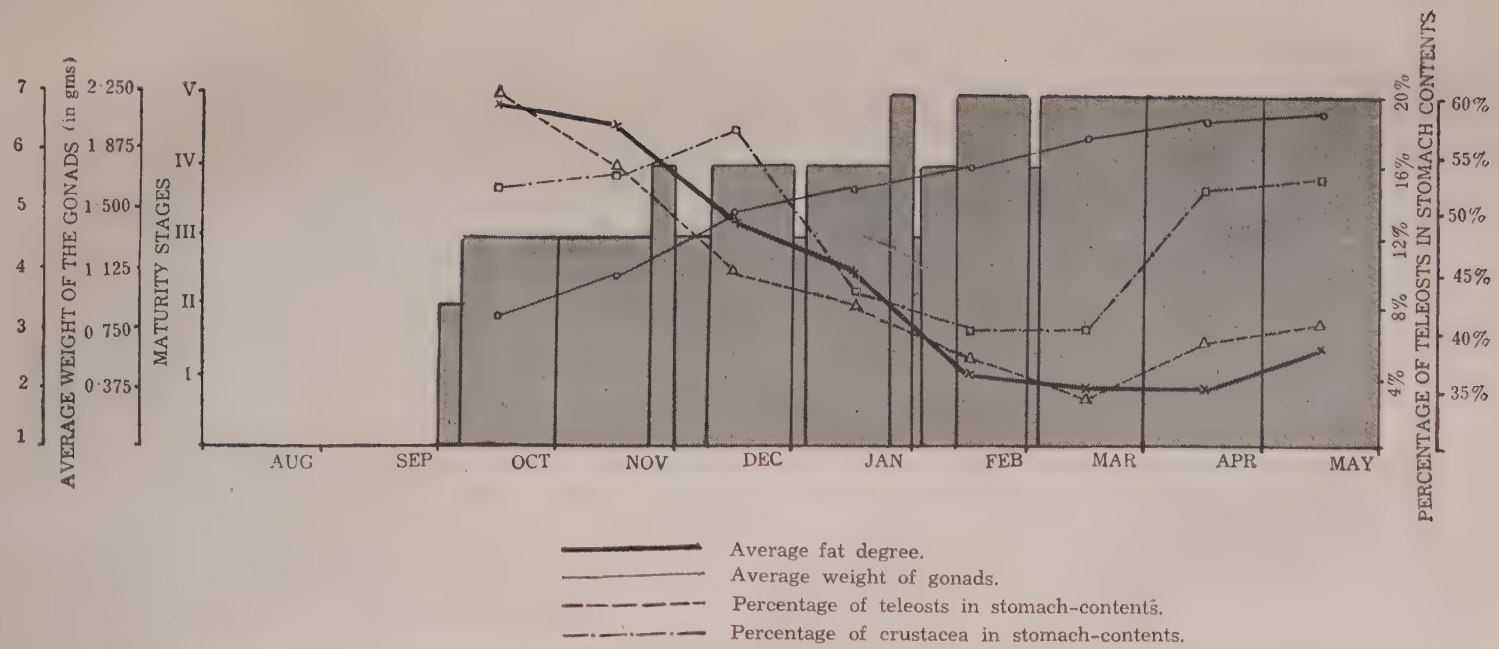


Fig. 9. Fat content, maturity and feeding (on Teleosts and Crustacea) in *P. hoevenii* of the 18-22 cm. group.

It has been stated above that there is a slight drop in fat value of the fish in November in spite of heavy feeding. Since in November all fish in this length-group are in maturity Stage III or above (Table IX) the decrease in fatness must be correlated with progress in maturity. The fat content decreases slightly in this month due to the greater expenditure involved by the development of gonads — an expenditure not fully compensated for by vigorous feeding (Fig. 9). This fact becomes clearer when we compare the fat content of the younger 13-17 cm. group. In these fish which are in maturity Stages I and II, the gonads do not take up fat and there is a rise in fat value correlated with the intense feeding. That the fat spent for maturation is responsible for the decline in the total fat value of the larger fish becomes more evident when these progress to the still higher stages of maturity in the next three months. By February the majority of these fish reach Stage V of maturation and the fat value rapidly falls to the lowest level — though during this period the poorer quality of food may also be partially responsible for the heavy loss of fat. After March when the fish advance beyond Stage V fat is not deposited in the eggs (Milroy 1898) and as a consequence, in May there is a rise in the amount of muscle fats. Figs. 8 and 9 indicate that the extent of depletion in fat that occurs in this length-group is much more than what it is in the previous length-group, 13-17 cms. These very large fish fall from a maximum fat degree of about 7 in October to a minimum of 2 in March; the maximum and the minimum of monthly averages for the 13-17 cm. group are 5·8 and 2·5 respectively. As has been shown, the process of maturation is one of the main factors responsible for the fat loss in both the large (13-17 cms.) and very large (18-22 cms.) size — groups during the period November to March but the rate of resorption of fat in the two length-groups due to this factor — maturation — varies firstly because in the smaller group, maturation begins later than in the larger (Vide Table IX) and secondly because, in the larger fish the larger gonad drains more of fat during maturation than the smaller gonad of the smaller-sized fish. The monthly means in the weights of the gonads of the fish in these two size-grades only lend support to this. The ovaries and testes of the very large fish (18-22 cms.) weigh far more than what they do in fish of the lower size-group (13-17 cms.) Table IX and (Fig 9). It would thus be apparent that the size-age factor of the fish influences the variations undergone by the tissue fat of the fish in different periods of the year.

TABLE IX

The maturity stages *Pellona hoevenii* of the length-groups 13-17 cms. and 18-22 cms. and the average weights of their gonads in different months.

Length-groups	Maturity Stages					Average weight of the gonads (in grammes)
	I	II	III	IV	V	
			AUGUST			
13-17 cms.	14	2	—	—	—	0·03
			SEPTEMBER			
13-17 „	13	7	—	—	—	0·05
			OCTOBER			
13-17 „	8	16	—	—	—	0·07
18-22 „	—	4	14	—	—	0·82
			NOVEMBER			
13-17 „	13	31	7	—	—	0·11
18-22 „	—	—	10	3	—	1·10
			DECEMBER			
13-17 „	13	16	28	5	—	0·21
18-22 „	—	—	5	11	—	1·50
			JANUARY			
13-17 „	1	2	6	4	—	0·40
18-22 „	—	—	3	20	6	1·70
			FEBRUARY			
13-17 „	—	1	3	4	2	0·67
18-22 „	—	—	1	8	14	1·80
			MARCH			
13-17 „	—	—	—	7	8	0·73
18-22 „	—	—	—	2	20	2·00
			APRIL			
13-17 „	—	—	—	5	17	0·91
18-22 „	—	—	—	—	5	2·10
			MAY			
13-17 „	—	—	—	3	12	0·94
18-22 „	—	—	—	—	6	2·13

Discussion

Though Brocklesby (1941) states that the "food intake of a fish controls its fat content", yet the full implications of the different aspects of the diet factor — such as the amount of food taken, changes in the nature of the diet, its quality etc., on fatness in fishes have not been fully elucidated so far except probably by Hickling (1947) in pilchards. Some workers (Channon and Saby 1932, Lovern and Wood 1937, Dixon 1937, Wilson 1939 etc.) would correlate the fat content of the muscles with the corresponding variations in the intensity of feeding. In *P. hoevenii* also the muscle fats exhibit an overall correlation with the volume of food consumed. Scrutiny of the tables setting forth this correlation will however reveal no direct and close correlation always. This is because the quality of food as well as the quantity taken in affects the production and storage of fat. From August to October and November when the muscle fats increase, the volume of food consumed and the proportion of the teleostean constituents of diet are the highest for the whole year. Crustacean items however reach the maximum in December. The fat content of the muscles registers a steep fall from December to March, but the rate of feeding at this time does not undergo a proportionate decrease. But there is a rapid decrease in the crustacean and teleostean items of diet from January to March, corresponding to the loss of fat observed during these months. In April and May more of these items enter the diet with a consequent increase in the amount of fat in the muscles. It will also be seen that the composition of the plankton is indirectly related to these changes in the fat value of the fish through the amount and nature of food made available to the fish. For according to Sewell (1913), in Indian waters, the plankton and copepods are numerous "during the months of November and December and then they gradually diminish" and "by the end of March and the beginning of April they are again present in large numbers".

As was stated before, maturation may be partly responsible for bringing down the value of fat-stocks of the fish. The appearance of fat globules in the gonad cells of these fish coincides with an increase in the weight of the gonad and an advance in maturity as well as a fall in the quantity of muscle fats. That these are not mere coincidences but correlated phenomena can be gathered from the studies on king salmon by Greene (1914, 1919), on pink salmon by Davidson and Shostrum (1936) and on different races of herrings by Lovern and Wood (1937). But by March the majority of the fish examined were in maturity Stage V, after which fats are not

deposited in the eggs (Milroy 1898). This probably helps in raising the fat value in April and May.

That the muscle fat of the herring is increased by age, independant of maturity, was first mentioned by Bruce (1924), Lovern (1938) finds that the fat content of the eel increases " almost linearly with length at least between certain limits ". But Channon and Saby (1932) do not consider that age may be related to fat in herrings. In the present investigation, fish included in higher length-groups were seen to be on the whole fatter, throughout the greater period of the year. This seems to be related not only to their greater intake of food but also to the inclusion of increasing amounts of teleosts, as an important item, in their diet.

Summary

1. The fat content of the muscles of *P. hoevenii* increases from August to October and November and thereafter decreases upto March. In April and May it rises again.

2. These fluctuations are seen to be related to corresponding changes in feeding and maturity of the fish.

Acknowledgment

The author is deeply indebted to Dr. C. P. Gnanamuthu, M.A., D.Sc., F.Z.S., Director, University Zoology Laboratory, Madras, for his help and guidance.

References

Brocklesby, H.N. (1941). Chemistry and technology of marine animal oils with particular reference to those of Canada. Bull. Fish. Res. Bd. Canada. Lix.

Channon H.J. and El Saby. (1932). Fat metabolism of herrings I. A preliminary survey. Biochem. J. XXVI.

Davidson and Shostrum. (1936). U.S. Bur. Fish. Invest. Rep. 33.

Dixon, B. (1937). The composition of the Polish Sprat catches in the Bay of Danzig in the season 1934 to 1935 and 35-36. Rapp. and Proc. Verbaux des Reunions Con. Perm. Internat. Mer. 102 Appendix. 1-12.

Greene, C.W. (1914). Storage of fat in the muscular tissue of king salmon and its resorption during the fast of spawning migration. Bull. Bur. Fisheries. Washington XXXLII. 69-138.

Greene, C.W. (1919). Biochemical changes in the muscle tissue of king salmon during the fast of spawning migration. Jour. Biol. Chem. 39. 435-456.

Hickling, A.F. (1947). The seasonal cycle in the Cornish Pilchard. Jour. Mar. Biol. Assoc. 26. 115-138.

Lewkowitsch. (1913). Chemical technology and analysis of oils, fats and waxes volume 1.

Lovern, J.A. (1938). Fat metabolism in fishes. XIII. Factors influencing the composition of the depot fat of fishes. Biochem. J. XXXII. 1214-24.

Lovern, J.A. and Wood, H. (1937). Variations in the chemical composition of herring. Jour. Mar. Biol. Assoc. XXII. 281-93.

Milroy, T.H. (1898). The Physical and chemical changes taking place in the ova of certain marine teleosts during maturation. Sixteenth Ann. Rep. Fish. Bd. Scotland. Part III. 135-152.

Moses, S.T. (1922). A statistical account of the fish supply of Madras. Madras Fish. Bull.

Patakoot, R.S., Pradhan, L.B. and Murti, N.N. (1950). Fat content of the muscles of some marine fishes of Bombay. Journal of the University of Bombay, XVIII. Part 5.

Sewell, R.B.S. (1913) Notes on the biological work of R.M.I.S. "Investigator" Jour. Asiatic. Soc. Bengal. Vol. 9.

Sekharan, K.V. (1949). Feeding and maturity in relation to fats in the muscles of the rainbow sardine. Jour. Madras Univ. Sec. B. Vol. XVIII.

Wilson, D.P. (1939). Variations in the fat content of the flounder. Jour. Mar. Biol. Assoc. 23.

TWO NEW SPECIES OF *IRONA* (ISOPODA) PARASITIC ON MADRAS FISHES

BY

S. Gopalakrishnan Nair, M.A.

Zoology Laboratory, Madras University

Introduction

Though the Indian Isopods have been studied and described by Alcock and Wood Mason (1891), Chilton (1924) and Chopra (1922-24) the parasitic family Cymthoidae has received comparatively less attention. Brief reference to these parasites have been made by N. K. Panikar and Gopala Iyer (1937), and Chidambaram and Devidas Menon (1945). The present paper deals with two new species belonging to the genus *Irona* which has not been recorded from India except for one specimen *Irona nanoides* from Ceylon.

Irona robusta. N. Sp. (Plate 1)

Host and record: Nearly 80 females and 25 males were collected from the gill region of a common market fish of Madras — *Tylosurus leiurus* (Bleeker) netted during February and March of 1950. The parasites were found covered partially by the gill operculum. Owing to this situation the body of the parasite is slightly twisted.

The types: The holotype (♀) and allotype (♂) will be lodged in the Indian Museum, Calcutta, the paratypes will be in the Zoological Laboratory, Madras.

Binomics: When brought to the laboratory nearly all the parasites were alive, though the host fishes were dead. When dislodged and removed to a finger-bowl the young females crawled about but the berried ones were found most often lying on their back. The males appeared capable of swimming about. Both the males and females were alive for four or five days. But when they were transferred to the gills of the living fishes, *Therapon jarbua* belonging to *Percidae,* they lived for fifteen days. Their subsequent death was probably due to the accidental death of these experimental hosts. The pleopods appear to be respiratory in function and are always seen in motion together with the telson.

Plate 1

Plate 2

The parasites cling to the host very tenaciously and the powerfully clawed legs as well as the mouth parts appear to help in prehension. They however do not seem to prove fatal to their fish-hosts since no injury whatsoever could be made out in the fishes examined.

Adult female. (Fig. 1)

Colour: All the sixty forms observed were milk white while alive and yellowish white, when preserved.

Size: The body measures 24 to 28 mm. in length when measured from the frontal margin to the posterior end of the telson. The large size of the present form is striking because the other species of this genus recorded so far do not measure more than 25 mm.

The body is ovately produced, almost twice as long as wide, much twisted especially at the junction of the thorax and abdomen. The dorsum is markedly convex.

The head is small, wider than long and projects only a little beyond the anterolateral margin of the first thoracic segment in which the head is deeply immersed.

The eyes are small, almost triangular with the sides slightly rounded and the apex pointing towards the mid-dorsal region.

Appendages:

The *first antenna* (Fig. 3) is eight-segmented and slightly compressed laterally.

The *second antenna* (Fig. 4) is also eight-segmented, more compressed laterally and has an acutely pointed terminal segment.

There are small dark spots scattered about in the segments of both antennae.

The *labrum* (Fig. 5) is broadly elliptical, about two and a half times wider than long and has the lateral sides rounded with a single dark spot on the left side.

The *mandible* (Fig. 6) has a broad basal segment to which is attached a two jointed palp on the outer side and a bent, broad, bimolar cutting plate on the inner side.

The *first maxilla* (Fig. 7) is long slender and styliform with 4 sharp spinules at the distal end.

The *second maxilla* (Fig. 8) is broader than the first and is about two and a half times longer than wide. The distal end is fairly rounded and slightly bilobed with three recurved hooks on the inner lobe and two on the outer.

The *maxilliped* (Fig. 9) is three segmented, the basal segment about two and a half times longer than wide. The distal end is conical and the third which is the smallest has five small recurved hooks arranged in a row.

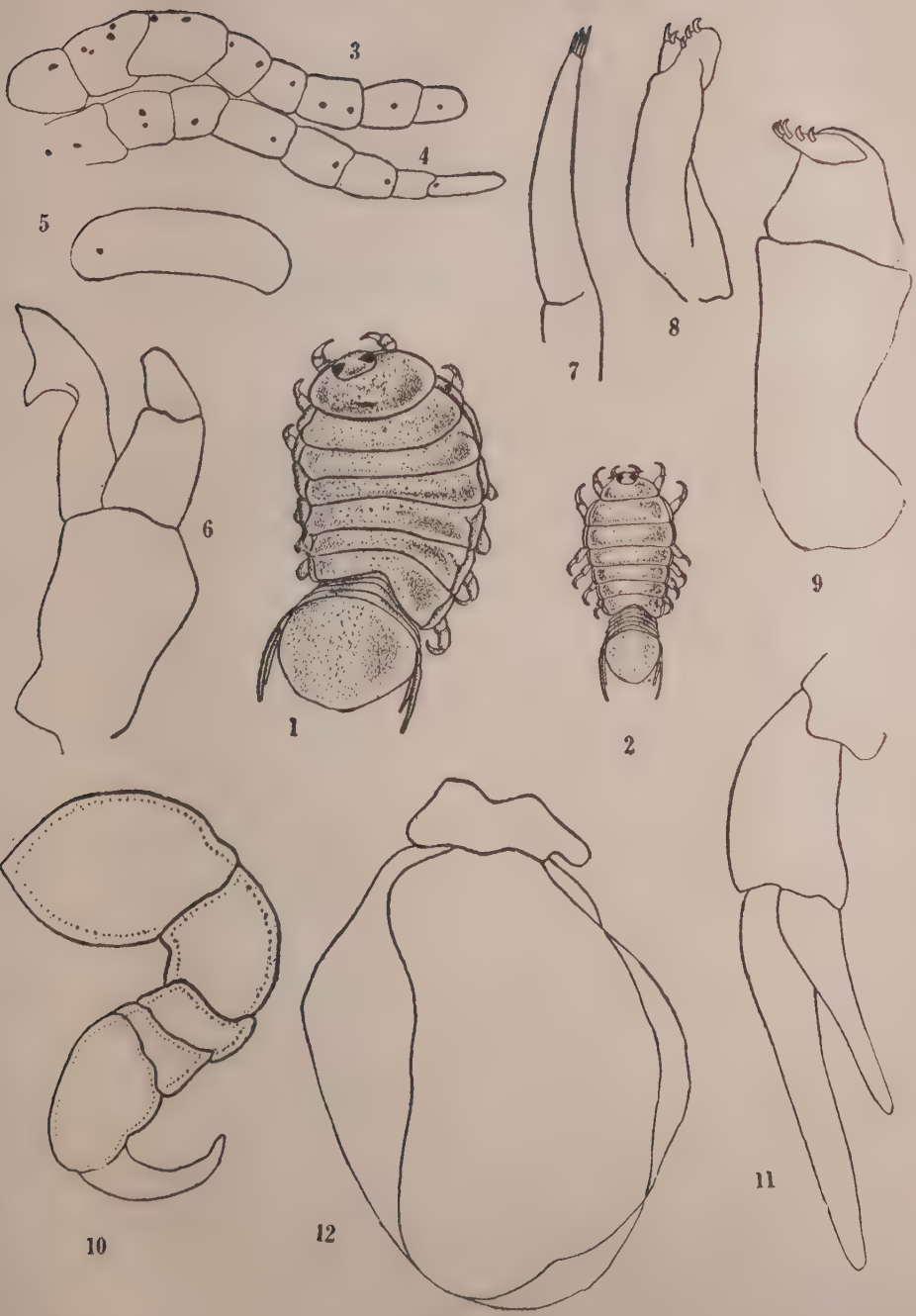
Thorax: The first thoracic segment is semicircular, very broad in the middle with a U shaped notch in the anterior margin. The sides are very widely rounded, the posterior margin of the second and third segments are broadly rounded, that of the fourth almost straight, the fifth, sixth and seventh increasingly concave.

Epimera: The first thoracic segment is devoid of an epimera. Hence there are only six pairs. These extend outwards but curve dorsally along their length and have acute posterior corners. Though the width of the plates increases as we go backwards the length varies with that of the segment. The posterior end of the first and second pair of epimera do not reach the hind margins of the respective thoracic segments but in the other thoracic segments which are shorter than the first two, the posterior limits of the epimera coincide with those of the segments.

Legs: (Fig. 10) There are seven pairs of short legs of which the posterior are longer. The first three pairs are directed anteriorly while the rest are turned caudalwards. Each leg is six-jointed, the basis is as long as broad, the ischium is smaller but bent, the merus and carpus are the smallest, the propodus is broad and rounded and bears a curved prehensile dactylus.

Marsupium: Four pairs of foleaceous plate-like oostegites are attached ventrally to the anterior ends of the four pairs of epimera belonging to the second to the fifth thoracic segments by means of narrow bent stalks. There are a large number of rib-like chitinus thickenings radiating from the part of attachment. The oostegites of either side imbricate medially and thus enclose a space which serves as a brood-pouch. Within this marsupium the eggs and even the larvae are protected.

The abdomen is very much immersed so that only the posterior four segments are discernable from the dorsal view. The lateral sides of the abdominal segments are much produced and obtusely rounded, the posterior margin being always a little concave and slightly wavy.



Figs. 1—12

The *telson* is almost round, slightly broader than long, membranous and exhibit minute granules on its surface.

The *Uropod* (Fig. 11) projects beyond the terminal segment. The basal segment is one and a half as long as wide. The outer ramus is a little longer and almost twice as broad as the inner one.

The *pleopoda* (Fig. 12) are all similar and membranous. The outer branch is slightly narrower than the inner. Both the branches have wavy margins.

Adult male. (Fig. 2)

Nearly 25 males were collected, the sex-ratio appears to be 1 : 3. It was usual to find the male attached to the gills of a side opposite to that where the female was located. Very rarely were they found on the same side. The male is nearly half the size of the female, being 11-14 mm. in length.

The *body* is elongated and oval, the length being more than twice the breadth, the tortion of the body is much less noticeable than in the females. The dorsum is convex especially in the anterior region of the thorax.

The head is small, slightly wider than long and less immersed than the female.

The *first antenna* is eight segmented as in the female. The terminal segment is more acute.

The *second antenna* is shorter than in the female though the basal three segments are relatively larger.

The mouth parts are as in the female excepting the mandible palp which is three segmented and bears a cutting plate which is less curved than in the female.

Thorax. The first thoracic segment is the broadest. The notch is less pronounced. The second and third are the widest.

The epimera of the second and third thoracic segments are relatively longer than the rest.

The *legs* are longer and more slender. The basis is almost rectangular, the width being two thirds the length. The dactylus is more acute and slender.

The *abdomen* forms nearly a third of the total length and as it is not so immersed, it is more conspicuous than in the female.

The *telson* is more or less semicircular, slightly broader than long. The posterior margin is more rounded than in the female.

Uropod: The terminal segment being only two-thirds the length of the Uropods, these appendages project beyond the posterior end of the telson. The inner ramus is only two-thirds the length and width of the outer ramus. The distal ends of both the rami are more or less bluntly pointed.

The *pleopods* are membranous as in the female.

Taxonomic remarks

The genus *Irona* was established by Schioedte and Meinert in the year 1884. They described four species *Irona Renardi, I. vatia, I. melanostica* and *I. nana.* Later *I. faveolata* (Hansen 1897) and *I. nanoides* (Stebbing 1902) were added making the total six. No other species was added since. These six forms constituting the genus are well marked only in the size of the body, the shape of the telson, the length and the disposition of the Urapods in comparison with the telson, whereas in the shape of the body, head, eye (which most authors have described) the differences are only slight. As regards the second antenna, the present form resembles *I. melanostica.* Detailed comparison with the other species appears to be of little value and as the authors have not described the mouth parts (except in *I. nanoides*). However the present form exhibits features not found in any of the six known species. The presence of dark spots on the two pairs of antennae, the broad elliptical labrum, and the minute granules on the telson can easily distinguish the present form from others. Hence it is treated as a new species — *Irona robusta* and may be defined as follows: — Large robust form with dotted eight-segmented first and second pair of antennae, elliptic labrum, U shaped notch in the first thoracic segment, minute granulated semi-circular telson and long Uropods which project beyond the telson.

Irona far. N. Sp. (Plate 2)

Host and records About 60 females and 23 males were collected from the gills of *Hemirhamphus far* (Day) caught between February and April of 1950 on the coast of Madras. These parasites like those of the previous species were found attached to the gills of the host, but the characterisic torsion of the body is not so conspicuous.

The types: The holotype (♀) and allotype (♂) will be lodged in the Indian Museum, Calcutta; the paratypes will be in the Zoological Laboratory, Madras.

Adult female. (Fig. 13)

Colour: The body is white with edges (the region of the epimera) tinged yellow. Deep black stripes marks the posterior margin of all the thoracic segments.

Size: 20-25 mm. in length.

The *body* is oblong, twice as long as wide and twisted either to the left or right.

The *head* is small, immersed, slightly wider than long and dorsally convex. The anterior margin is rounded and projects slightly beyond the first thoracic segment.

The *eyes* are large, oval, deep black in colour with dark granules all over it. The two eyes together occupy two thirds the width of the head.

Appendages:

The *first antenna* (fig. 15) is of eight segments of which the first three basal segments are specially stout.

The *second antenna* (fig. 16) is narrower than the first, eight segmented, the distal segment being more pointed.

Both the antennae have small dark spots scattered all over the surface.

The *labrum* is very small, narrow, about three times as long as wide and directed posteriorly. It bears two dark spots.

The *mandible* (fig. 17) is like that of *Irona robustus* in structure. The basal joint is more stout and carries a three jointed palp on the outer side. On the inner side there is a two-segmented ramus of which the distal one has a bimolar cutting edge.

The *first maxilla* (fig. 18) is a slender stylet-shaped structure tipped with four sharp spinules.

The *second maxilla* (fig. 19) is more flat and indistinctly bifid, the inner of the two carrying three and the outer two recurved hooks.

The *maxilliped* (fig. 20) is of three broad, slightly flatter joints, the first joint is nearly twice as long as the second. The second joint is nearly as broad as long and articulates with the third joint which is only one third the length of the second joint and carries three inwardly pointed spines.

All the oral appendages except the first and second pair of maxillae have a few deep dark spots at their basal segments.

Thorax: The anterior margin of the first thoracic segment has a deep almost rectangular notch in the middle into which the head is immersed. The sides of the first and second thoracic segments are broadly rounded where as their posterior margins are rounded. The posterior margin of the third and fourth segments are almost straight, but those of the last three are deeply concave. All the thoracic segments have deep dark colouration at the posterior margin which is very characteristic of the species. The colouration is deeper in the posterior three thoracic segments and it gradually becomes lighter towards the anterior segments until it is seen only as two faint dark lines on the postero-lateral margins of the first thoracic segment.

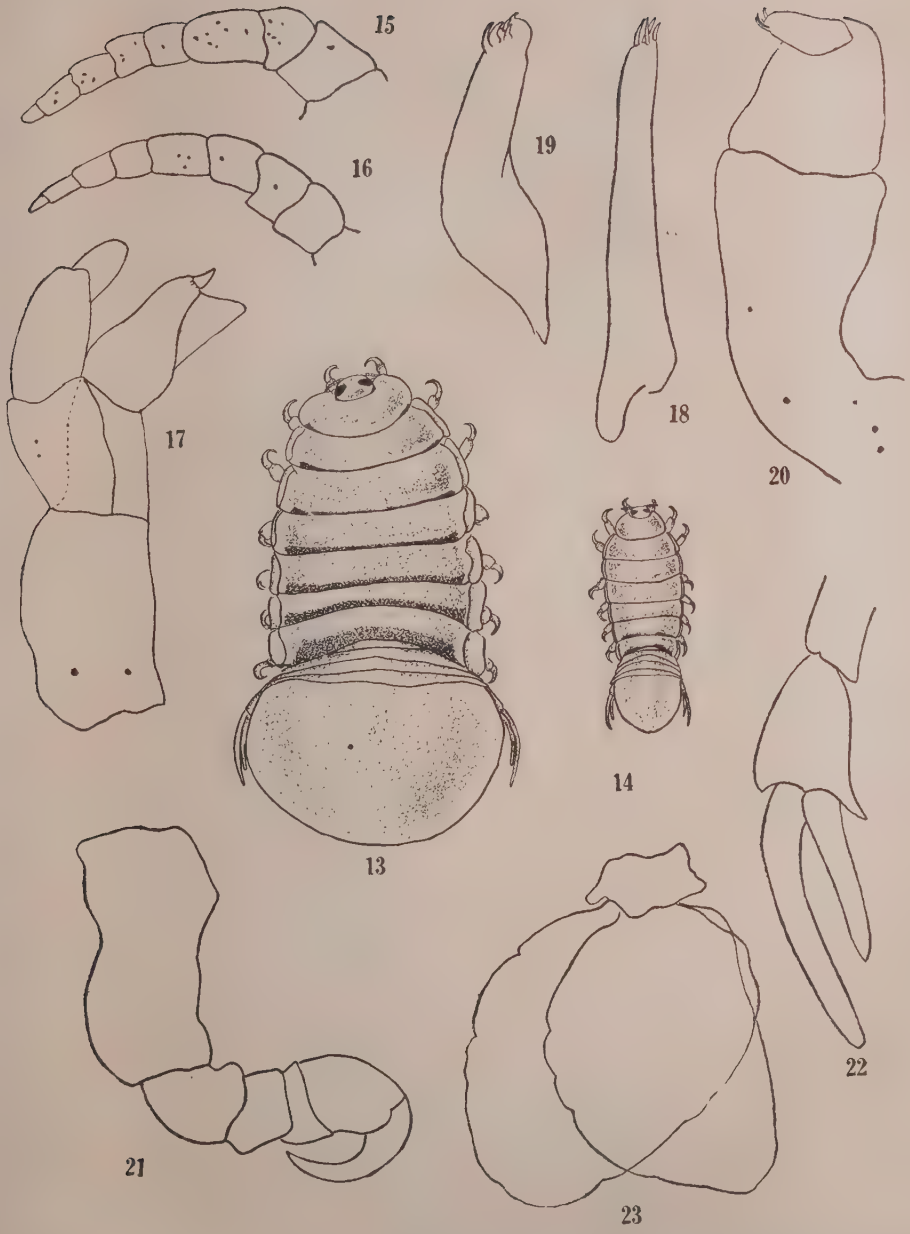
Epimera: The first thoracic segment is devoid of an epimera. Hence there are six pairs of epimera, one pair for each succeeding segment. The first and second pair are long with acutely rounded posterior corners. The epimera gradually increase in width towards the posterior ones. The four anterior epimera do not quite reach the posterior angle of the segment, while the last two epimera extend a little beyond the posterior angles of the respective segments.

Legs: (fig. 21) There are seven pairs of legs which increase gradually in length, posteriorwards, the seventh pair being the longest. The first three pairs are turned anteriorly where as the posterior four are directed caudal-wards. The basis is stout, almost twice as long as wide and equal in length to the ischium, merus, carpus and propodus put together. The ischium is almost triangular in outline, its attachment with the basis being very narrow and strong. The merus and carpus are comparatively narrower. The propodus is of considerable size and holds the strong hook-like dactylus.

The *abdomen* is deeply immersed, the first two segments being covered by the last thoracic segment while the sides of the third is covered at least on one side. The posterior margin of the first four segments are widely sinuated, that of the fifth almost straight excepting the two ends which are bent posteriorly. The postero-lateral angles of the adbominal segments are produced and are obtusely rounded.

The *telson* is almost semicircular and membranous.

The *Uropod* (fig. 22) is shorter than the telson. The outer branch is more obluse and a little bent. It is a little wider and and a quarter longer than the inner ramus which is almost straight and acute.



Figs. 13—23

The *pleopods* (fig. 23) are faleaceous, the two branches being transparent, rounded with wavy margins. The two branches are equal in size with slight variation in some cases. The pleopods and telson are seen in a state of constant movement when alive. It appears to aid in respiration.

Adult male (fig. 14)

About 23 males were collected, the sex ratio appears to be nearly 1 : 3. The males as in *Irona robusta* are found in the gills opposite to the one infested by females. The female agrees with the male to a large extent in the morphological details.

The *colour* is the same as in the female but much paler.

Size : The male parasite is much smaller than the female, the length of the body measuring 14-16 mm.

The *head* is small, immersed and slightly convex at the posterior margin.

The appendages resemble those of the female very closely but differs in having fewer number of dark spots on the cephalic appendages.

The *epimera* project out from the thorax. The first and second are the longest, the third being the smallest is broader than the first and second. The outer margin of the first and second epimera are broadly rounded while it is slightly concave in the posterior ones.

The *legs* are longer and more slender in the males. The basis is short and of equal length and breadth. Its joint with the ischium is wider than that of the female. The dactylus is longer, acute and dentate in the inner margin.

The *Uropod* is equal to the telson in length if not a little longer. They project widely on either side.

The *pleopods* are foleaceous, the outer branch being slightly larger than the inner.

Taxonomic remarks

The present form resembles the foregoing species in the eight-jointed first and second pairs of antennae being marked by the black spots, the bimolar cutting plate of the mandible, the styliform first maxilla bearing four spinules, the faintly bilobed second maxilla having five hooks and in the deeply notched first thoracic segment. But it differs from it in the presence of spots on all the oral appendages except the maxillae, the deep dark stripes found at the posterior margin of the thoracic segments, the presence of only three spines in the maxilliped, in the semicircular telson and

in the Uropods being shorter than the telson. The form is therefore treated as a new species and may be defined as follows :—

Moderately large sized forms with dotted antennae and mouth parts, with the thorax exhibiting the characteritsic striations, with much immersed abdomen, and a semi-circular telson. The uropods extend as far as the telson, in males but shorter in the females.

ACKNOWLEDGMENT

It is my pleasant duty to express my grateful thanks to Dr. C. P. Gnanamuthu, M.A., D.Sc., F.Z.S., Director, Zoology Laboratory, Madras University for the guidance and help and to Mr. S. Krishnaswamy for his many valuable suggestions.

REFERENCES

1. Alcock and Wood-Mason, J. Ann. Mag. Nat. Hist. (b), VII, 1891, pp. 270-271.
2. Chidambaram and Devadas Menon. Curr. Sci. 14, 11, 1945.
3. Chilton. Fauna of Chilka Lake. Mem. Ind. Mus. Calcutta, 5, 1924, pp. 875-895.
4. Chopra, B. Records of the Indian Museum 1923, 25, 411-543.
5. Hale, H. M. The crustaceans of S. Australia, Part II, 1929, pp. 201-380.
6. Hansen, H. J. Bull, Mus. Comp. Zool. Harward, XXXXI.
7. Panikar, N. K. and Aiyar, R. G. Curr. Sci. 5, 1937, pp. 429-30.
8. Richardson, H. Bull. U.S.N. Mus. No. 54, 1905.
9. Schioedte and Meinert. Nat. Tidsskr, ser. 3, Vol. 14, pp. 327-381.
10. Stebbing, T. R. R. Ceylon Pearl Oyster Fisheries and Marine Biology Reports. Parts IV, 1905, pp. 1-64.
11. Stebbing, T. R. R. Ann. S. African Mus. 10, pp. 373, 1914.
12. Thielemann, Martin.* Wiss. math. phys. kl Suppl. Bd2. ABL 3(1-109) 2 Taf. 282.

* Not referred in the original.

FIGURES

1. Irona robusta. Female (× 2).
2. „ Male (× 2).
3. First antenna (× 28).
4. Second antenna (× 28).
5. Labrum (× 28).
6. Mandible (× 28).
7. First maxilla (× 28).
8. Second maxilla (× 28).
9. Maxilliped (× 20).
10. First thoracic leg (× 6).
11. Uropod (× 6).
12. First pleopod (× 6).
13. Irona far Female (× 3).
14. „ Male (× 2).
15. First antenna (× 20).
16. Second antenna (× 20).
17. Mandible (× 20).
18. First maxilla (× 20).
19. Second maxilla (× 20).
20. Maxilliped (× 20).
21. First thoracic leg (× 6).
22. Uropod (× 6).
23. First pleopod (× 6).

PLATES

1. Irona robusta ; female and male.
2. Irona far ; do.

A NOTE ON THE PARASITES OF FREE LIVING COPEPODS OF MADRAS

BY

S. KRISHNASWAMY

Zoology Laboratory, Madras University

In the course of the examination of the plankton, some copepods infected by parasites were collected though no special care was taken to search for the infected forms. The copepods served as hosts for a variety of parasites such as *Gregarines, Blastodinium,* Larval Helminths and Isopods. In all the cases, the pathological effects, if any, appeared not so serious as to prove lethal and owing to the minute size of the host as well as the parasites, the life histories of the parasites could not be followed. Hence only brief notes on the parasites are given in the present note.

Gregarine (Fig. 1)

The parasite which measured 460 μ was of a dirty greenish yellow colour and was found inside the body cavity of *Sapphirina metallina* (male) and *Sapphirina ovato-lanceolata* (female). The protoplasm inside the body of the parasite appears to be granular The anterior end of the parasite could be differentiated from the rest of the body by its being dilated and knob-like.

Steuer (p 611, 1910) who found it on *Sapphirina gemma* identified it as *Ophiodina heckeli* Ming. However Jepps (1937) who found it in *Calanus finmarchicus* states that " in the present lamentable state of our ignorance concerning this group, it does not seem profitable to attempt to name this *Gregarine,* beyond pointing out that it belongs to *Cephalina* ".

Blastodinium ? :

A *Blastodinium* is frequently found inside the alimentary canal of *Canthocalanus pauper, Acrocalanus longicornis* and *Clausocalanus arcuicornis.*

The parasite which ranges between 30 μ — 450 μ in length is dirty yellow in colour and spindle shaped. Most of the parasites found were in sporulation and contained a number of 'spores' enclosed in a transparent cover (Fig. 2).

The ovaries of Copepods infected by *Blastodinium* were in a condition of extreme degeneration.

Larval Helminths :

Two types of larval helminths have so far been taken and are being described here as type A and B.

Type A. (Fig. 3)

Each larva measures 40 μ in length and was found actively moving about when they were squeezed out of the host. The infected Copepod was a female *Undinula vulgaris.* More than 500 of these larvae were found in a single host on 15-11-48. The whole body cavity was filled with these larvae.

The infected Copepod was brick-red in colour and very conspicuous.

Type B :

A single parasite measuring 400 μ was found in *Paracalanus aculeatus* in September. The whole body cavity was occupied by the parasite as shown in the figure (Fig.4).

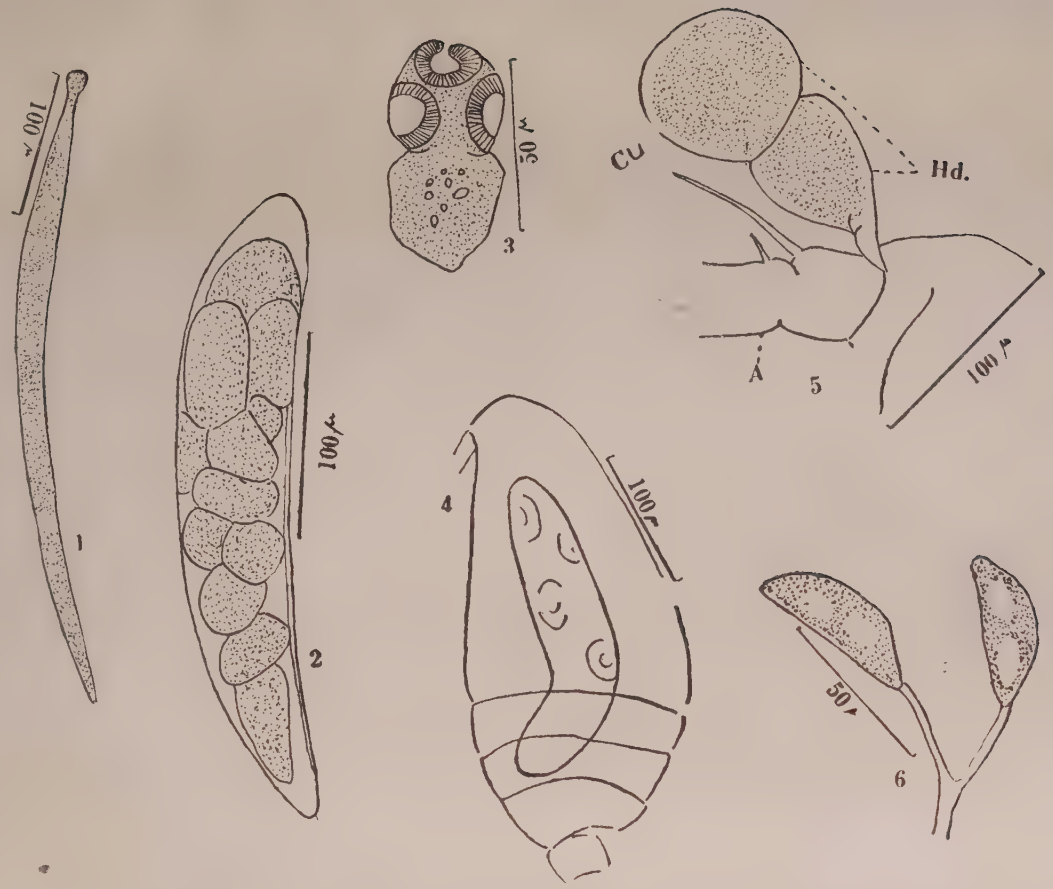
These parasites appear to have a very strong effect on the host as in both the cases where they were found, the ovaries were very degenerate

Microniscus :

The Isopod ectoparasite, *Microniscus* has been taken on a number of occasions. This has been found parasitic on *Acartia erythraea, Acrocalanus longicornis, Eucalanus crassus Tortanus gracilis, Labidocera minuta* and *Canthocalanus pauper.* The parasite was found attached to the cephelothorax of the host in an oblique position, the posterior part of the parasite being on the lateral side of the host with the anterior end extending over the dorsal side. Three of the common types, *Microniscus acartii, M. eucalanii* and *M. platyfrons* parasitic on *Acartia, Eucalanus* and *Acrocalanus* have been described by Gnanamuthu and Krishnaswamy (1948).

Ellobiopsis chattonii Caullery :

This parasite, whose systematic position is not definitely known yet, was found on a male *Canthocalanus pauper* collected on 22-1-1948.



Figs. 1—6

The club-shaped parasite is attached to the first joint of the right antennule by a root and it measures 160 μ in length. It is two segmented and each segment is usually referred to as a 'head' (Fig. 5 Hd). There is an outer covering or cuticle (Fig. 5 Cu) and the protoplasm inside appears to be granular. No 'cone' or 'plug' described by Jepps (loc. cit) could be made out. This may be due to the parasite being not quite mature. Jepps is of opinion that this parasite does not have any apparent effect on the host.

The occurrence of this on Copepods has been recorded by Scott (1896), Caullery (1910), Chatton (1910), Apstein (1911), Willey (1920), Steuer (1928), Marshall, Nicholls and Orr (1934) and Jepps (1937) who found it on *Calanus finmarchicus, C. helgolandicus, Pseudocalanus sp.* and *Pleuromma sp.*

The systematic position of this parasite is not definitely determined by these authors. Scott (1896) referred to it as an "? infusorian parasite", Caullery and Chatton (1910) considered it to be a dinoflagellate while Jepps (1937) suggester a "fungus relationship".

The present record is also of interest because male *Calanus* showing any kind of parasite is rare as noted by Marshall et al. and Jepps.

Besides these parasitic forms, the copepods also bear epiphytic diatoms.

Epiphytic diatom, Amphora sp: (Fig. 6)

These are found as bushy outgrowths on the cephalothorax and abdomen of species belonging to the genus *Corycaeus.*

These appear as bushy clusters of spindle shaped forms which are transparent and colourless or light yellow in colour. Each spindle shaped diatom measures 15 μ in length and two such are attached to a stalk. The whole colony is dichotomously branched

Steuer (p. 617, 1910) reproduces the figure of this diatom on *Corycaeus* given by Giesbrecht (1892) and states that although Giesbrecht has figured this diatom which is usually found bordering the cephalothorax and abdomen of copepod, he has not mentioned it in the text. Klevenhusun (1934) who recorded this on *Corycaeus specious* established it as belonging to the genus *Amphora.*

This is the first record of its occurrence in Indian waters.

ACKNOWLEDGMENT

The author takes this opportunity to express his grateful thanks to Dr. C. P. Gnanamuthu, Director University Zoology Laboratory for guidance and help and Dr. R. B. Seymour Sewell, F.R.S. of Cambridge, for valuable suggestions.

REFERENCES

Apstein, C.* 1911. Parasiten von *Calanus finmarchicus*. Wiss. Meeres. N.F. 13.

Chatton, E.* 1920. Arch. Zool. Exp. Gen. Vol. 59.

Gnanamuthu, C. P. and Krishnaswamy, S. 1948. Isopod parasites of free living copepods of Madras. Proc. Ind. Acad. Sci. B. Vol. XXVII, 119-126.

Hyman, H. 1940. The invertebrates. Protozoa through Ctenophora. Magraw Hill Publ.

Jepps, Margaret W. 1937. Notes on Apstein's parasites and some very early platyhelminths. Parasitologyy, Vol. 29, pp. 554-558.

Jepps, Margaret W. 1937. Protozoan parasites of *Calanus finmarchicus* in Clyde sea area. Q.J.M.S. Vol. 79, p. 58.

Klevenhusen, W. 1933. Beitrag zur systematik und Biologie der corycaen nach dem material der Meteor expedition. Zool. Jahrb. Syst. Vol. LXIV, pp. 583-602.

Marshall, S. M., Nicholls, A. G. and Orr, A. P. 1933-34. On the biology of *Calanus finmarchicus* J.M.B.A. (N.S.) Vol. 19, pp. 793-818.

Sewell, R.B.S., 1947. Free swimming planktonic copepoda systematic account. John Murray Exped. Sci. Reports. Vol. VIII, No. 1.

Steur. A. 1910. "Planktonkunde" Berlin.

Steur. A. 1932 * "Copepoda 6. Pleuromamma Giesbrecht. 1898. der Deutschen Tiefsee — Expedition wiss ergeb. der Deutchen Tiefsee — Expedition, Vol. XXIV.

Willey, A. 1920. Copepoda. Report of the Canadian Arctic Expedition Pt. 7 K.

* Not refered in the original.

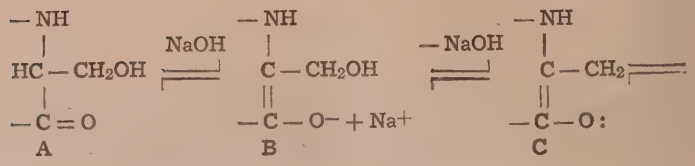
THE ABSENCE OF FORMATION OF DEHYDROPEPTIDE LINKAGES IN ALKALI-TREATED PROTEINS

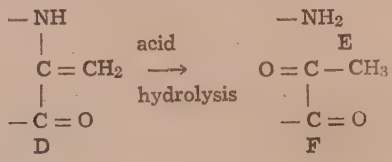
BY

L. K. Ramachandran and P. S. Sarma
University Biochemical Laboratory, Chepauk, Madras

It is well known that the ammonia and certain other dismutation products found in protein hydrolysates result from the destruction and alteration of the amino acid constituents. Amongst studies on the destruction and dismutation products of amino acids, the hydroxyamino acids, serine and threonine have attracted particular attention. Thus, it has been observed that serine is slowly destroyed by boiling acid (1, 2, 3, 4), the destruction being to the extent of 10% under usual hydrolysis conditions (5, 6). Serine residues carrying a phosphoric ester group have been noted to be greatly labile to acid (1, 7). Threonine in the free state was found to be more resistant to boiling acid than serine (6, 8), the destruction increasing on autoclaving (9). The dismutation products of serine have been studied in some detail (10, 11). It has also been shown that serine residues in silk fibroin and casein are greatly labile to alkali (1, 12).

Nicolet, Shinn, and Saidel (12) found that serine and threonine are indeed subject to partial destruction when in protein combination, under conditions which do not measurably affect them in the free state, and that this destruction takes the form of elimination of water to form (in the case of serine) what is presumably a dehydroalanyl grouping in the protein. These groupings were claimed to have the capacity to form cystine derivatives, which yielded ammonia on further acid hydrolysis which appears in addition to the usual 'amide-NH_3'. They treated proteins (cf. silk fibroin) with boiling dilute alkali in an atmosphere of nitrogen for 1-2 hrs., and showed by further acid hydrolysis that the additional 'amide-NH_3' now observed closely accounted for more than 91% of the serine and threonine that had been destroyed. They interpreted this as an approximate proof for the dehydrostructure of the intermediate products in the following mechanism of action which they suggested :





No positive proof was adduced. Thus, Nicolet et al postulate that when proteins are treated with boiling dilute alkali, dehydroalanyl units (e.g. serine) result from the modified hydroxyamino acids. This is indirectly postulating the formation of unsaturated amino acid units in the protein molecule, and therefore of the probable presence of the dehydropeptide structure. The dehydropeptide linkage in such a case may be represented as follows (13):

$$R^1CH\cdot CO-NRC\ (=CHR^1)\ CO-NHR$$

$$\rightleftharpoons R^1CHCON=C\ (CH_2R^1)\ CO-NHR$$

The report of Bergmann and Schleich (14) on the presence of a new enzyme, the dehydrodipeptidase in the kidney of sheep and pigs which is capable of splitting exactly such a bond in a dehydrodipeptide suggested the following investigation to observe whether such linkages were present in alkali-treated protein. The pH of optimum activity of the enzyme was reported to be 7·5, and the splitting of the bond could occur only at the dipeptide stage and it needed a free carboxyl at the amino carbon atom. They also demonstrated that ordinary proteinases (polypeptidases) and dipeptidases were without effect on such a bond in a substrate. In the case of a typical substrate as glycyldehydrophenylalanine the hydrolysis was represented thus:

$$C_6H_5\cdot CH_2\cdot C\cdot COOH \quad \rightarrow \quad C_6H_5\cdot CH_2\cdot CO\cdot COOH$$
$$\|$$
$$N\cdot CO\cdot CH_2\cdot NH_2$$
$$+$$
$$NH_2\cdot CO\cdot CH_2NH_2$$

We have adopted the measurement of the keto acids produced as an index to the extent of hydrolysis of such bonds by the enzyme.

The alkali-treated and non-treated casein substrates employed in the investigation, were first digested with pepsin and trypsin, or pepsin, trypsin and erepsin successively so as to ensure the conditions necessary for the working of the dehydrodipeptidase.

Experimental

Materials used :

Casein (Light white soluble B.D.H.) — Nitrogen 15·75% ; Moisture 10·24% ; Ash 3·327%. Serine = 5·0% of total N. Threonine = 3·4%.

Pepsin and *Trypsin.* B.D.H.

An *Erepsin* extract was obtained thus : Intestinal mucosa fresh from slaughtered pigs was ground up with sand and four times its weight of 87% (w/w) glycerol in a mortar, placed in a stoppered bottle under toluene and allowed to autolyse for a day at room temperature. The whole was centrifuged. 1 vol. of the centrifugate was diluted to 3 vols. with cold water, centrifuged, a tenth vol. of N/10 acetic acid was added to the centrifugate and again centrifuged. The centrifugate was used for ereptic digestion, after adjusting the pH.

The *Dehydrodipeptidase* (DHDP) extract was prepared as follows: 61g. of tissue fresh from the kidneys of slaughtered sheep were minced fine, ground up with sand and 244g. 87% (w/w) glycerol. The whole was placed in well stoppered conical flask under toluene and allowed to autolyse for a day, after which it was centrifuged. The centrifugate was used for the digestions. Stored in the refrigerator the enzyme extract retains its activity for long periods.

Method of estimation of keto acids :

A standardisation curve for keto acid estimations was obtained by using a standard butanone solution. Calibration curves for keto acids and other carbonyl compounds are identical if these are plotted in terms of scale reading and molar concentration (15). Using the Lumetron photoelectric colorimeter and an yellow-green (540mμ) filter, linearity between scale reading and molar concentration was obtained for the range 0·00008 millimoles to 0·0016mM per c.c. of reaction mixture of final vol. 10 c.c.

To 4 c.c. of solution containing the keto acid was added 1 c.c. of a 0·1% (w/v) solution of 2-4—dinitrophenylhydrazine in 2N HCl. Allowed to stand at room temperature for 5 mins., at the end of which were added 5 c.c. 2·5 N NaOH. Comparisons were made exactly after 9 mins. after addition of alkali, against corresponding blanks.

The estimation in the enzymic digests was made as follows: 5 c.c. digest treated with 2 c.c. 10% trichloracetic acid, allowed to stand for 5 mins., and centrifuged. 0·2-0·4 c.c. of centrifugate diluted to 4 c.c. was used for the estimations of keto acids present, comparisons being made against the corresponding control digests.

Enzymic digestions, etc.

A. 10g. casein boiled with 150 c.c. 0·1 N alkali (NaOH) under reflux for an hour in an atmosphere of nitrogen. Addition of capryl alcohol was found helpful in suppressing the heavy frothing.

B. The control run was performed under the same conditions, 10 g. casein being boiled with 150 c.c. distilled water, instead of the alkali.

Both were cooled, and pH adjusted to 1·6. Digested each with 1·0 g. pepsin at 36° for 7 days. Final volume of digest—200c.c.

At the end of the period the digests were adjusted to pH 8·5, and both digested with 0·5 g. trypsin for 14 days. Total vol. 202·6 c.c. (I). At the end of the period both the formol titre and the value for keto acids present in the digest was obtained.

20 c.c. of the above tryptic digest was separately placed and to it was added 5 c.c. of kidney extract. Final pH 7·5. Incubated for 9 days, at the end of which period both formol titre and the keto acids value for the digest were noted. (II)

130 c.c. from the rest of the tryptic digest was treated with 20 c.c. of erepsin solution. pH 7·6. Digested 10 days. At the end of the period both formol titre and the value for keto acids present was noted. (III).

To 132 c.c. of the above ereptic digest was added 30 c.c. of kidney extract. pH 7·5. Incubated for 4 days, at the end of which both formol titre and keto acids value was again noted. (IV).

In all digestions care was taken to add a layer of toluene to prevent bacterial infection. In all digests the formol titre was higher in the case of the control (B), those for A being consistently lower.

The results are tabulated on page 83.

Casein sample	Keto acid values in digests per g. substrate.				Difference in formol litre from control digest expressed in c.c. 0·1083N NaOH, per g. substrate.			
	At end of Tryptic digestion. I	Tryptic digest further digested with DHDP II	At the end of ereptic digestion III	Ereptic digest further digested with DHDP IV	I	II	III	IV
	Millimoles	Millimoles	Millimoles	Millimoles				
A. Alkali treated Casein.	0·7164	0·7116	0·6548	0·5463	16·65	18·82	17·04	18·30

(Colorimetric comparisons in all cases made against corresponding control digests as blanks.)

Discussion.

Since the enzyme digests (peptic and tryptic) of alkali-treated as well as non-treated casein (Control B) and also a separate enzyme control all gave colour values using 2-4-dinitrophenylhydrazine, the keto acid values for the digests of the alkali-treated casein (I, II, III, IV) were obtained in all cases using digests of the control (B) as the blanks. Thus any increase in keto acid values from I to II or III to IV in the digests of alkali treated casein on a per g. substrate basis would mean dehydropeptide linkages were being hydrolysed. But the results in the table indicate absolutely no measurable increase from I to II or III to IV. In the latter case there is actually a decrease in III and more in IV, which presumably may be due to the destruction of chromogenic groups or units present in the earlier digests. Computing on a complete alteration of the hydroxyamino acids present an increase of 0·9075 mM keto acid per g. substrate should be observable. Based on the destruction of 38% of the total hydroxyamino acids present, determined through a periodate-NH_3 procedure (5), the result of the alkali treatment of casein should have caused an increase of 0·3449 mM keto acid per g. of substrate from I to II or III to IV. We find from digests I to II absolutely no increase in the keto acids values. Thus there is no evidence for the hydrolysis of dehydropeptide linkages, and this points to the absence of formation of such linkages in alkali treated casein.

As regards the difference in formol titre of the control (the higher) from A, it was noted that in spite of the progressive hydrolysis from digests I to II and from III to IV, the difference calculated on a basis of 1 g. of the substrate remained somewhat constant, thereby indicating that the peptide bonds modified by alkali treatment equivalent to the above difference in titre are non-hydrolysable by either pepsin, trypsin, erepsin or the kidney dehydrodipeptidase. The possibility is that the alkali treatment of the protein has caused a certain amount of racemisation, the enzymes obviously remaining incapable of splitting bonds between such constituent racemic amino acids of the protein molecule. It is well known that alkali causes widespread racemisation of the constituent amino acids of the protein molecule with greater ease than when they are in the free state, especially so at a higher temperature (16).

Summary.

Evidence is presented to show the absence of formation of dehydropeptide linkages when proteins (cf. casein) are treated with alkali under conditions described.

The change occurring is, presumably, only one of widespread racemisation; the formation of NH_3 in amount equivalent to hydroxyamino acids destroyed or modified, during alkali treatment, on further acid hydrolysis being possibly ascribable to some change other than the formation of dehydroamino acid units in the protein molecule.

Literature Cited

1. Damodaran, M. and Ramachandran, B. V. (1941)—Biochem. J. *35*, 122.
2. Boyd, M. J. and Logan, M. A. (1942)—J. Biol. Chem. *146*, 279.
3. Abderhalden, E. and Broich (1933) — Biochem. Z. *262*, 321.
4. Botvinnik, M. M. and Morozova (1943)—Compt. Rend. Acad. Sci. URSS., *41*, 70.
5. Gordon, A. H., Martin, A. J. P., and Synge, R. L. M. (1941)—Biochem. J. *35*, 1369.
6. Rees, M. W. (1946)—Biochem. J. *40*, 632.
7. Posternak and Posternak (1928)—Compt. Rend. *187*, 313.
8. Winnick, T. (1942)—J. Biol. Chem. *142*, 461.
9. Borchers, R., Totter, J. R., and Berg, C. P. (1942)—ibid., *142*, 697.
10. Daft, F. S. and Coghill, R. D. (1931)—ibid., *90*, 341.
11. Plimmer, R. H. A. and Lowndes (1938)—Compt. Rend. Trav. Carlsberg (Ser. Chim) *22*, 434.
12. Nicolet, B. H., Shinn, L. A., and Saidel, L. J. (1942)—J. Biol. Chem. *142*, 609.
13. Price, V. E. and Greenstein, J. P. (1948)—ibid., *175*, 969.
14. Bergmann, M. and Schleich, H. (1932)—Z. Physiol. Chem. *205*, 65, *207*, 235.
15. Sealock, R. R. and Sherp, H. W. (1941)—J. Biol. Chem. *140*, CXIV.
16. Martin, A. J. P. and Synge, R. L. M. (1945)—" Advances in Protein Chemistry ", Vol. II. Chapter on ' Analytical Chemistry of the Proteins '.

A STATISTICAL STUDY OF THE IMPORT TRADE OF INDIA DURING 1900-'38

BY

O. SURYANARAYANA, B.A. (HONS.)

Research Student, Department of Statistics, University of Madras

1. INTRODUCTION

A statistical study of the import trade of India is of very great importance due to the following reasons. She relied on the foreign imports for some consumption goods like sugar, grain pulse and flour. Her steady industrial development during the period 1900-'38 necessitated an increase in the imports of certain raw materials and unmanufactured articles; e.g., large quantity of cotton raw and waste which were needed by local industry. The imports of "Articles wholly or partly manufactured" increased over this period necessitated by the developments of the industries in India. The quantum of imports registered an upward trend till 1913-'14 when the outbreak of World War I had a disastrous effect on the trade of India. The exigencies of war, the consequent reduction of the shipping space, the preoccupation of European countries in the supply of war demands lead to a fall in the volume of trade. This was followed by a boom in the post-war period and a depression in the early thirties which was a world wide catastrophe. In this paper an attempt is made to study exhaustively the fluctuation of import trade of India during the period of 38 years from 1900-'01 to 1937-'38 by suitably constructing the volume indices, determining the trend and studying the fluctuations for finding significant periods by statistical analysis of the data. A study relating to the export trade of India during this period was made by Cheriyan in his thesis for M.Sc. in the year 1943 (unpublished).

Source of data:

The data for the analysis are taken from the "Annual Statements of the Sea-borne Trade of British India". (1900 to '38) published by the Department of Commercial Intelligence and Statistics, India. As the number of commodities imported is too large for detailed analysis, a list of thirteen commodities in the three main groups,

I. Articles of food and drink
II. Raw materials and unmanufactured articles
III. Articles wholly or mainly manufactured,

is chosen for study. The value of these commodities taken constitute nearly 75% of the value of the entire trade of the year and hence they are taken as representatives of the import trade. The data considered here consist of the figures of value and quantity of the six commodities in groups I and II and the value figures alone for the seven commodities in Group III since the quantity figures for some of the latter are not available. The articles chosen for the study are as follows :—

GROUP I

Articles of Food and Drink

1. Grain, pulse and flour
2. Liquors
3. Sugar
4. Spices

GROUP II

Raw materials and unmanufactured articles

5. Oils — vegetable, animal and mineral
6. Cotton — raw and waste.

GROUP III.

Articles wholly or mainly manufactured

7. Chemicals, Drugs and medicines
8. Dyes and colours
9. Machinery of all kinds
10. Metals and manufactures thereof
11. Cotton yarn and manufactures
12. Paper, paste-board and stationery
13. Electrical goods and apparatus.

As we are concerned with the study of the volume of trade, it was necessary to obtain uniform quantity figures for the items in Group III. This is done by deflating the value series (3) from the " Annual Statements of the Sea-borne Trade of India 1900-'38 " by the corresponding Price Indices taken from " Index numbers of Indian Prices 1861-1926 " and " The statistical Abstract for British India from 1930 to '31 to 1939-'40 ", published by the Department of Commercial Intelligence and Statistics, India. The index relatives of the quantity figures of the articles in Groups I and II and of the quantity figures of Group III, obtained by deflation are calculated, taking the base as the average of the five pre-war years 1909-'10 to 1913-'14. This particular base is chosen because of the normality of the trade during these years. These index relatives are given in Table I.

TABLE

Index relatives of quantity of

Year	Grain, pulse and flour	Liquors	Sugar	Spices	Oils, vegetable animal, mineral	Cotton, raw and waste
1900-01	667·5	75·1	36·1	67·5	89·8	91·4
1901-02	193·7	82·1	41·2	61·3	109·9	31·9
1902-03	88·7	87·0	37·4	67·4	98·0	27·4
1903-04	47·7	91·2	43·4	66·6	88·4	7·4
1904-05	29·2	100·0	47·5	79·2	91·9	78·1
1905-06	212·5	109·4	56·3	80·7	68·0	65·5
1906-07	179·1	105·4	76·0	88·4	70·8	47·2
1907·08	199·6	107·8	76·6	88·9	89·3	63·9
1908-09	651·5	98·8	82·7	89·9	106·8	50·9
1909-10	169·2	97·3	86·3	94·6	85·4	38·1
1910-11	76·2	95·7	101·2	108·2	87·7	18·4
1911-12	65·1	96·0	83·8	100·0	117·5	195·9
1912-13	63·0	105·0	105·8	98·8	104·7	223·9
1913-14	126·5	106·0	122·8	98·5	104·8	23·7
1914-15	264·4	86·2	75·3	106·0	117·3	37·1
1915-16	390·2	75·4	88·0	104·6	105·4	11·3
1916-17	86·7	69·6	74·3	101·5	96·6	14·5
1917·18	30·0	53·8	69·9	91·2	69·0	21·0
1918-19	406·2	55·7	72·0	108·8	65·9	38·2
1919-20	1143·4	70·8	66·0	96·0	157·1	26·9
1920-21	15·61	89·8	47·1	80·1	136·7	75·7
1921-22	3080·0	70·4	107·2	83·0	133·9	198·4
1922-23	188·4	71·9	69·0	96·8	144·6	87·0
1923-24	201·3	74·0	65·2	113·0	183·8	103·6
1924-25	48·2	83·1	99·9	98·9	204·2	164·1
1925-26	257·4	88·9	110·0	113·0	219·2	142·5
1926-27	368·4	97·8	126·4	107·5	199·8	370·8
1927-28	1098·7	111·2	112·7	86·4	254·6	536·3
1928-29	5105·7	106·1	126·5	114·0	265·9	235·1
1929-30	2625·3	118·4	138·5	127·8	276·8	194·6
1930-31	1894·4	112·2	137·4	104·1	265·3	479·5
1931-32	1067·7	85·5	76·2	98·1	—	643·7
1932-33	525·5	84·6	55·0	98·3	—	687·8
1933-34	848·9	75·9	36·1	105·5	—	348·1
1934-35	2838·9	76·8	30·6	116·6	—	491·5
1935-36	1614·1	80·0	27·6	126·2	—	620·8
1936-37	683·2	79·2	3·2	135·8	—	527·5
1937-38	9119·8	76·8	1·97	127·2	—	1091·2

I

the items in Groups I, II and III

Chemicals, drugs and medicine	Dyes and colours	Machinery of all kinds	Metals and manufactures there of	Cotton yarn and manufactures	Paper, paste-board and stationery	Electrical goods and apparatus
63·5	38·0	45·1	47·7	66·6	48·4	—
63·5	44·4	60·1	50·7	73·4	53·4	—
72·2	50·8	62·5	59·2	75·8	60·3	—
75·4	60·1	73·1	68·3	75·5	61·2	—
74·2	53·7	83·1	65·9	87·6	65·6	—
74·2	53·2	98·4	69·3	94·7	68·0	51·5
73·0	48·6	105·8	72·2	83·5	69·2	85·1
76·6	48·4	102·9	84·2	88·7	74·7	67·7
80·7	82·5	123·6	85·4	76·8	77·6	69·4
99·4	93·0	102·4	89·2	85·2	91·1	70·5
96·8	100·5	88·7	86·7	88·1	91·6	75·7
98·9	95·8	77·4	89·1	94·0	92·3	93·5
97·9	106·4	96·0	98·2	111·4	107·0	113·3
107·5	104·4	135·5	136·9	121·4	117·9	147·1
102·0	91·1	108·7	85·6	92·1	97·3	118·5
102·8	47·9	69·1	63·0	63·5	83·1	93·9
77·7	53·3	48·9	37·6	47·8	79·4	78·3
85·7	49·5	38·3	29·6	46·2	68·0	72·0
76·2	54·2	38·9	40·0	44·9	71·4	79·4
106·9	95·4	100·6	89·3	69·3	103·3	135·8
96·4	110·2	165·0	111·7	67·9	196·6	239·2
85·8	106·1	298·6	92·5	53·5	86·1	285·4
101·9	113·4	233·0	91·5	74·7	111·2	171·9
111·6	119·9	201·1	92·9	74·9	112·6	187·4
100·9	104·8	140·5	87·3	81·3	107·0	145·5
103·8	81·5	144·3	85·7	66·7	105·8	170·8
130·6	101·4	143·6	85·9	71·5	120·7	206·9
141·6	125·9	178·3	116·0	75·4	127·9	245·3
150·1	137·6	218·0	118·5	79·2	152·2	293·0
168·9	126·6	218·4	101·3	75·0	169·4	339·9
162·7	131·4	184·9	69·4	34·5	141·4	316·8
186·7	146·8	165·7	47·2	30·6	143·3	266·4
184·1	135·9	154·1	38·2	41·3	155·7	269·8
202·9	145·3	200·5	43·2	29·7	155·2	288·7
222·9	181·0	208·8	52·3	38·2	168·9	369·0
240·3	193·9	226·1	98·6	37·1	185·5	404·7
221·3	177·1	232·5	79·3	30·7	176·4	398·0
219·9	186·7	239·6	92·9	23·1	207·7	385·0

2. The Trend

From the index relatives, it is obvious that the trend of the trade is effected greatly by the outbreak of War in 1913-'14. So far the study of the trend, the entire period is split into two parts, the period before the termination of the War (1900-'01 to 1918-'19) and the period after the war (1919-'20 to 1937-'38). The trend component, that exists, in any series may be accounted by several methods — the method of (i) least squares, (ii) the moving averages, or (iii) fitting a curve by orthogonal polynomials. The method (ii) is quite unsuitable for the analysis since it will introduce spurious oscillations into the residual fluctuations which we are using in the calculation of volume indices. The method (iii) * (4) is simpler involving less computation than (i) and is employed in this analysis. The trend curves upto the third degree are fitted in succession to the index relatives of quantity of all the commodities for the two periods 1900-'01 to 1918-'19 and 1919-'20 to 1937-'38 which have been denoted as short term A and short-term B respectively and the entire period (1900-'38) as the long term. The first, second and the third order regressions for each commodity are tested for significance and on this result the order of fit was determined. The complete analysis is set out in tables in Appendix. The equations of the trend curves with the best fit are given there in terms of

ξ_1, ξ_2, ξ_3 where

$\xi_1 = (t-10)$ for the short term A

$\xi_1 = (t-10)$ for the short term B

$\xi_1 = (t-19{\cdot}5)$ for the long term,

$\xi_2 = \xi_1{}^2 - 30$ and $\xi_3 = \xi_1{}^3 - 53{\cdot}8$, t being the time variable $t = 1, 2, 3 \ldots\ldots\ldots 38$ to represent the years 1900-'01, 1901-'02, 1902-'03,.....1937-'38. It is seen from the regression analysis that the second order regression is uniformly adequate for all the commodities in the three groups except to the items (3), (5), (6), (7) and (12). Hence it is expected that the scond degree fit will be suitable in general for the long term trend (1900-'38) and the second degree curves are fitted without further analysis. The second degree trend curves are taken uniformly to all the commodities for the short term A, short term B and the long term and the second degree trend values are calculated for the items in the three groups. Taking Y for the quantity relative at the time t, the equations of the trend curves obtained are given on page 91 :—

Equations of the trend curves:—

SHORT TERM A:

1. Grain, pulse and flour.	$Y = 365{\cdot}48 - 38{\cdot}615\,t + 1{\cdot}757\,t^2$
2. Liquors.	$Y = 66{\cdot}23 + 8{\cdot}98\,t - 0{\cdot}513\,t^2$
3. Sugar.	$Y = 7{\cdot}87 + 13{\cdot}310\,t - 0{\cdot}523\,t^2$
4. Spices.	$Y = 53{\cdot}25 + 5{\cdot}960\,t - 0{\cdot}179\,t^2$
5. Oils, vegetable animal and mineral.	$Y = 84{\cdot}14 + 2{\cdot}655\,t - 0{\cdot}136\,t^2$
6. Cotton raw and waste.	$Y = 19{\cdot}52 + 11{\cdot}537\,t - 0{\cdot}598\,t^2$
7. Chemicals, drugs and medicines.	$Y = 50{\cdot}34 + 6{\cdot}703\,t - 0{\cdot}256\,t^2$
8. Dyes and colours.	$Y = 16{\cdot}16 + 9{\cdot}660\,t - 0{\cdot}554\,t^2$
9. Machinery of all kinds.	$Y = 24{\cdot}18 + 17{\cdot}269 - 0{\cdot}881\,t^2$
10. Metals and manufactures thereof.	$Y = 118{\cdot}78 - 14{\cdot}034 + 0{\cdot}716\,t^2$
11. Cotton yarn and manufactures.	$Y = 50{\cdot}65 + 9{\cdot}787\,t - 0{\cdot}529\,t^2$
12. Paper, paste-board and stationery.	$Y = 30{\cdot}65 + 9{\cdot}83\,t - 0{\cdot}394\,t^2$
13. Electrical goods and apparatus.	$Y = 37{\cdot}61 + 16{\cdot}425\,t - 0{\cdot}955\,t^2$

SHORT TERM B:

1. Grain, pulse and flour.	$Y = 1568{\cdot}96 - 265{\cdot}439\,t + 21{\cdot}6\,t^2$
2. Liquors.	$Y = 59{\cdot}15 + 7{\cdot}610\,t - 0{\cdot}371\,t^2$
3. Sugar.	$Y = 65{\cdot}40 + 20{\cdot}190\,t - 1{\cdot}193\,t^2$
4. Spices.	$Y = 154{\cdot}96 - 10{\cdot}19\,t + 0{\cdot}413\,t^2$
5. Oils, vegetable animal and mineral.	$Y = 122{\cdot}22 + 9{\cdot}910\,t + 0{\cdot}310\,t^2$
6. Cotton raw and waste.	$Y = 41{\cdot}84 + 17{\cdot}840\,t + 1{\cdot}150\,t^2$
7. Chemicals, drugs and medicines.	$Y = 82{\cdot}29 + 4{\cdot}55\,t + 0{\cdot}207\,t^2$
8. Dyes and colours.	$Y = 106{\cdot}02 - 1{\cdot}780\,t + 0{\cdot}342\,t^2$
9. Machinery of all kinds.	$Y = 187{\cdot}70 - 3{\cdot}514\,t + 0{\cdot}302\,t^2$
10. Metals and manufactures.	$Y = 100{\cdot}99 - 1{\cdot}542\,t - 0{\cdot}013\,t^2$
11. Cotton yarn and manufactures.	$Y = 66{\cdot}77 + 2{\cdot}045\,t - 0{\cdot}244\,t^2$
12. Paper, paste-board and stationery.	$Y = 127{\cdot}62 - 3{\cdot}350\,t + 0{\cdot}380\,t^2$
13. Electrical goods and apparatus.	$Y = 184{\cdot}76 + 0{\cdot}934 + 0{\cdot}580\,t^2$

LONG TERM TRENDS (1900-38).

1. Grain, pulse and flour.	$Y = 667{\cdot}12 + 111{\cdot}710\,t + 4{\cdot}920\,t^2$
2. Liquors.	$Y = 90{\cdot}77 + 0{\cdot}243\,t - 0{\cdot}017\,t^2$
3. Sugar.	$Y = 19{\cdot}88 + 8{\cdot}192\,t - 0{\cdot}210\,t^2$
4. Spices.	$Y = 64{\cdot}57 + 1{\cdot}801\,t - 0{\cdot}015\,t^2$
5. Oils, vegetable animal and mineral.	$Y = 115{\cdot}78 - 7{\cdot}570\,t + 0{\cdot}420\,t^2$
6. Cotton raw and waste.	$Y = 132{\cdot}93 - 22{\cdot}00\,t + 1{\cdot}010\,t^2$
7. Chemicals, drugs and medicines.	$Y = 26{\cdot}19 + 6{\cdot}059\,t - 0{\cdot}051\,t^2$
8. Dyes and colours.	$Y = 55{\cdot}46 + 0{\cdot}114\,t + 0{\cdot}084\,t^2$
9. Machinery of all kinds.	$Y = 55{\cdot}36 + 3{\cdot}420\,t + 0{\cdot}03\,t^2$
10. Metals and manufactures.	$Y = 12{\cdot}28 + 9{\cdot}270\,t - 0{\cdot}230\,t^2$
11. Cotton yarn and manufactures.	$Y = 75{\cdot}75 + 1{\cdot}515\,t - 0{\cdot}075\,t^2$
12. Paper, paste-board and stationery.	$Y = 30{\cdot}42 + 5{\cdot}554\,t - 0{\cdot}056\,t^2$
13. Electrical goods and apparatus.	$Y = 61{\cdot}373 + 1{\cdot}966\,t + 0{\cdot}256\,t^2$

The trend values for each commodity — the short term A, B and the long term — are given in table IV (a), (b), (c) in Appendix. These trends are represented in the graphical form for each commodity in the figures I, II and II.

Study of the trends :

The trends during the short term periods separately and for the whole period are studied from those trend curves and the following conclusions are drawn :—

Period from (1900 to 1919) :—

The trend of imports for each of the thirteen commodities except one i.e., grain, pulse and flour where it is flat shows uniformly a gradual rise reaching a miximum about the year 1909-'10 and a decline towards the end of this period. Further it is noticed that the level reached at the end of the period is almost the same as the beginning in the case of the items (5), (6), (8), (9) and (11) higher in the items (3), (4), (7), (12), (13) and lower in (2), (10) indicating that the rates of decline after 1909-'10 are respectively equal to, less than and greater than the rates of rise before this year.

The gradual rise in the trend of the imports in the beginning of this period is to be attributed to the natural consequences of the general economic prosperity throughout the world. Also the general decline in the imports in the latter half of this 19 year-period is mainly due to the war period when the Indian trade shrank considerably due to her suppliers like England and the other continental countries being completely occupied with the successful prosecution of the war.

Period from (1919 to 1938) :—

Unlike in the period 1900-'19, the trend curves during this period do not show the uniform tendency. In the item (1), i.e., grain, pulse and flour, although the fluctuations are irregular, the fitted trend curve shows that there is a decline from 1919 to '25 and a rapid rise towards the close. The rise in the trend of imports towards the end is mainly due to the inadequacy of the internal production in satisfying the country's need. The trend curves of the commodities (4), (9), (12) are almost flat showing that the imports of these items are uniform throughout this period. The items (5), (6), (7), (8), (13), continuously rise during this period, some of them i.e., (5), (6), (7), (13) at a rapid rate. The steady rise in the imports of mineral-oils is due to the development of the

transport and the increased consumption of the illuminants within the country. The rapid spread of electricity in the country and also the establishment of new factories have increased the India's demand for electrical instruments and apparatus. The large volume of imports of the item (7) mainly chemicals, may be explained by the establishment of the new industries within the country requiring these chemicals for their processes which are not produced internally. The imports of the items (2) (3) show a gradual rise reaching a maximum about the year 1927-'28, and a decline towards the end of this period. The decline in (3) can be explained by the protection granted to the sugar industry. In items (10), (11) the trend curves exhibit a gradual decline during this period. The decline in the imports of the item (11) i.e., cotton yarn and manufactures is due to the effect of the development of home cotton mill industry, hand-loom industry and the Swadeshi Movement.

Period (1900 to 1938):—

Next we will study the trend in the entire period from the trend curves fitted for that period. The trend of the imports of (1), (5), (6) shows a decline from the beginning of this period to 1909-'10 and a rapid rise towards the end of this period. The rise in the raw cotton imports is a reflection of the higher stappled cotton requirements of the local mills. It is a well known fact that India does not produce a large amount of long stappled cotton and hence has to be imported. The trend curves of the items (4), (7), (9), (12), (13) continuously rise from the beginning to the end of this period. The rise in (9) may be explained by the increasing demand of the local industry after the World-War I. The trend of imports of (2), (8), (11) are almost flat during this period due to the steady and uniform imports of those items. A rise from the beginning of this period to 1919-'20 and a gradual decline till the end of this period is noticed in the trend curves of the commodities (3) and (10).

3. Fluctuations About the General Trend

The index relatives of quantity for each year are expressed as percentages of the corresponding long term trend values and the fluctuations from the general trend are obtained by subtracting them from 100. These fluctuations are given in Tables V, (a), (b), (c) in Appendix and their graphs are shown in Figure IV. The fluctuations of the various commodities over the whole period are studied and the following conclusions are drawn:

In the item (1) i.e., grain, pulse and flour, the fluctuations are so erratic showing many peaks and troughs at the years $t = 10$, 16, 20, 23, 30 and $t = 5$, 18, 21, 28, 34, respectively. The fluctuations of the commodities (5), (8), (11) show a major peak before 1914-'15 followed by a similar trough during the war-period i.e., 1914-'19. The peak is due to the excessive dependence on the foreign imports which was a result of the absence of the local industrial production. The trough in the war period is due to the inability of the importing countries to produce our needs. Even if they produced, the nonavailability of the shipping space prevented them from exporting the goods.

The items (2), (7), (9), (10), (12), (13), exhibit a minor peak prior to the period 1914-'15 and a major trough in the war-period. The commodities (3), (4), (7), (11), (12) show normal fluctuations in the first half of the period 1900-'19 and the items (4), (6), (7) throughout the period 1900-'38 due to the steady demand. The peak before the year 1929-'30 followed by a major trough during the depression period 1930-'35 is seen in the fluctuations of the items (3), (9), (10), (11). The items (3), (10), (11) are not only influenced by the world-wide catastrophe of 1929, but also by the protection granted by the indigenous industry. The machinery and mill works is affected to a great extent by the depression. The order in which the commodities are affected by the general depression are as follows :—

Sugar (3)
Metals and manufactures thereof (10)
Cotton-yarn and manufactures (11)
Machinery of all kinds (9).

Fluctuations of Groups and the Total :

To study the fluctuations of the import trade of the three groups of commodities mentioned in section (2), volume indices for each group are necessary. This is effected by combining the fluctuations for the individual commodities tabled in Tables IV, (a), (b), (c) by taking their weighted means. The weights are appropriately the value figures since the relative importance of the commodities is judged alone by their values. Cheriyan* (5) in his paper "Some aspects of the Indian Export Trade 1900-'38" (from his thesis 1943 for M.Cc. unpublished) has employed this method. By a similar method, the total fluctuations for all these commodities together are obtained and are given in Table II. The three groups fluctuations as well as the total are represented graphically and from the study of these graphs, the following inferences are made :

TABLE II

Showing fluctuations about the general trend for each of the groups of commodities and for the total

Year	Commodities in Group I	Commodities in Group II	Commodities in Group III	Total for all the Commodities
1900-01	58·91	34·79	—	49·69
1901-02	16·85	21·55	—	18·76
1902-03	—10·36	5·56	—	—3·89
1903-04	—14·37	—5·01	—	—10·71
1904-05	—15·77	2·02	—	—9·17
1905-06	—11·32	—23·85	4·66	—15·50
1906-07	—1·01	—27·33	—3·97	—9·25
1907-08	—3·20	—8·52	2·45	—4·99
1908-09	+21·67	5·30	—1·26	3·06
1909-10	—2·81	—15·45	4·04	1·53
1910-11	8·89	—12·84	4·66	4·25
1911-12	—8·02	70·19	9·76	12·03
1912-13	11·81	87·55	28·91	30·97
1913-14	27·85	6·35	55·42	48·78
1914-15	—9·15	21·91	18·52	14·64
1915-16	4·61	12·61	—11·55	—6·62
1916-17	—9·12	6·24	—27·36	—21·68
1917-18	5·34	—22·97	—21·59	—16·72
1918-19	4·47	—0·78	—10·42	—7·06
1919-20	—18·58	13·60	—6·03	—6·89
1920-21	—39·03	—5·19	4·27	—3·00
1921-22	41·56	18·17	7·26	14·82
1922-23	—38·98	—17·43	7·99	—0·43
1923-24	—42·00	—6·08	5·67	—1·79
1924-25	—26·69	—0·12	5·33	0·05
1925-26	—20·60	—4·70	—7·67	—9·35
1926-27	—13·78	9·14	—0·24	—1·68
1927-28	—14·93	35·53	14·64	12·33
1928-29	117·61	—3·57	25·23	39·90
1929-30	24·52	—8·67	21·94	19·36
1930-31	7·17	0·53	—17·05	—10·20
1931-32	—27·96	—	—23·51	—24·30
1932-33	—34·12	—	—16·18	—18·61
1933-34	—35·04	—	—16·56	—18·88
1934-35	—14·61	—	—0·41	—2·16
1935-36	—19·49	—	17·03	12·74
1936-37	3·01	—	10·03	9·51
1937-38	88·79	—	15·04	27·46

The fluctuations in the imports of the commodities of Group I which are articles of food and drink are seen to be normal till end of the World War I i.e., 1919. So this shows that the import trade of the items of this group is not much affected by the war. A major peak before 1929 followed by a similar trough in the depression period is noticed in the fluctuations of the trade of these items showing the prominent effect of the world-wide depression of 1929 on these imports. Also the trough at 1920-'21, 1923-'24 in these fluctuation may be due to the post-war effect on the import trade of the items of this group. In the group II, covering oils-vegetable, mineral and animal, cotton raw and waste, two prominent peaks at 1912-'13 and 1927-'28 in the fluctuations of the imports are observed, the former being higher than the latter. The imports of the items of this group are not as much influenced as that of Group I. In the last group "Articles wholly or mainly manufactured," a peak before 1914 followed by a trough in the war period and similarly a peak followed by a trough in the depression period is evident in the fluctuations of the imports. A trough in the war period is accounted by the fact that our exporting countries like England are mainly occupied with their war production. The effect of depression is also clear on the items of this group.

The fluctuations in the total import trade including all the commodities, covered in our study, are similar to that of group III, as is seen from the Fig. V. The two booms at 1913-'14, 1928-'29 and the two depressions at 1916-'17, 1931-'32 are prominent in these fluctuations indicating that the world-war and depression have considerably affected the import trade in general.

4. The Investigation of the Periods of the Series

After describing the fluctuations of the import trade of India during 1900-'38 by commodities and groups, we proceed to study the regularity of the fluctuations of the trade by finding its periods. Harmonic analysis is applied to the series of the combined indices of fluctuation figures given in Table II. This series is also analysed by the Periodogram technique.

Harmonic Analysis :

The method employed for determining the period of the fluctuations and testing its significance, is that given by H. O. Hartley * (8) in his article "Tests of significance in the harmonic analysis" (Biometrika, Vol. 36, June 1949). The sequential procedure involved is briefly given here :—

Let Yt be an observed value at the time t and we fit to the observations the polynomial regression equation.

$$Yt = as + \sum_{i=1}^{m} \left(ai \cos. \frac{2\pi ti}{n} + bi \sin. \frac{2\pi ti}{n}\right) \qquad (i)$$

Let $Si^2 = ai^2 + bi^2$ be the observed intensities corresponding to the the period i. If R^2 is the residual sum of squares given by

$$R^2 = \sum_{t=o}^{n-1} (y_t - Y_t)^2 \text{ then}$$

$$R^2 = \sum_{t=0}^{n-1} (y_t - Y)^2 - \frac{n}{2} \sum_{i=1}^{m} ai^2 + bi^2 = \sum_{t=0}^{n-1} (y_t - Y)^2 - \frac{n}{2} \sum_{i=1}^{m} Si^2 \ldots (ii)$$

Provided $m \leqslant \frac{n-1}{2}$.

The ratio $\frac{n/2 \times Si^2/2}{R^2/n - 2m - 1}$ has been shown to be approximately distributed as F with 2 and $(n - 2m - 1)$ degrees of freedom. The procedure consists in taking first the maximum of the intensities, S^2max and this maximum intensity is considered significant at $\alpha\%$ level if the ratio $\frac{\frac{1}{2}\, n/2\, S^2max}{R^2/n - 2m - 1} \ldots\ldots$ (iii) exceeds 100 $\alpha/m\%$ point of the F-distribution with 2 and $(n - 2m - 1)$ degrees of freedom. If it is found significant the maximum intensity among the remaining Si^2's is taken and the value of ratio (iii) with this new S^2max. is referred to the F scale with the same degrees of freedom and compare with the 100 $\alpha/m - 1\%$ point. If this gives significance, we proceed similarly with the next largest intensity and take the 100 $\alpha/m - 2\%$ point. The process is continued until an an insignificant result is obtained. If the intensity found thus insignificant is Sk^2, K is the period of the series.

In our date n = 38 and taking m = 14, which is expected to be greater than the period required, the co-efficients * (7) ai, and bi, in (1) and the intensities Si^2's are calculated and the sums of squares $(\frac{n}{2} Si^2)$ with the degrees of freedom are set out in the analysis of variance table (Table III). Choosing the 5% level and following the procedure described above, the period of our import trade is determined to be seven years.

TABLE III

Relating to the Harmonic analysis of the total fluctuations
Analysis of Variance Table

	Sum of squares	D. F.	Mean square	F-ratio
Total	12493·51	37	—	—
Period i = 1	105·29	2	52·65	1·08
2	164·29	2	82·15	1·69
3	5202·76	2	2601·38	53·45
4	1152·01	2	576·01	11·83
5	2793·81	2	1396·90	28·70
6	473·77	2	236·89	4·87
7	725·28	2	362·64	7·45
8	361·74	2	180·87	3·72
9	129·43	2	64·71	1·33
10	84·57	2	42·28	0·87
11	667·10	2	333·55	6·85
12	58·50	2	29·25	0·60
13	15·99	2	7·99	0·16
14	120·83	2	60·42	1·24
Residual	438·14	9	48·68	—

Peroidogram analysis :—

This result was checked by applying the periodogram analysis * (6) to the series. The coefficients and the intensities for several trial periods, μ's are given in Table VI in Appendix and the periodogram in Fig. V. The maximum peak corresponds to $\mu = 7$ so that the period obtained to be 7 years which agrees with the result of the Harmonic Analysis.

5. SUMMARY

The study of the import trade is made by examining the general trend and the fluctuations about the trend. There is considerable similarity in the fluctuations of the different commodities reflecting the effects of the first world-war 1914-'19 and the general depression 1929-'35. It is also shown that the total import trade has a seven year period.

My thanks are due to Mr. D. V. Rajalakshman, Lecturer in Statistics, University of Madras, for his guidance in the investigation of this paper. I also acknowledge my thanks to Prof. P. B. Patnaik for his assistance in the later stages.

REFERENCES

1. "A statistical analysis of the foreign trade of India" by M. H. Venkata Subbiah.

2. "Trade of India" by Palekar.

3. "Trends in the foreign trade of India during the past sixty years" by N. S. R. Sastry and N. T. Mathew Sankhya, 1939-40.

4. "Statistical Methods for research workers by R. A. Fisher, 1938. Page 153.

5. "Some aspects about the Indian export trade", during 1900-'38" by K. C. Cheriyan.

(Thesis for the M.Sc. Department of Statistics, University of Madras, Unpublished).

6. "Advanced Statistics", Volume II, by M. G. Kendall.

7. "The Combinations of observations" by Brunt.

8. "Tests of significance in the harmonic analysis" by H. O. Hartley, Biometrika, Vol. 36, June 1949.

APPENDIX : TABLE

Short term

Year	Grain, pulse and flour	Liquors	Sugar	Spices	Oils, vegetable, animal and mineral	Cotton, raw and waste
					Short term — A	
1900-01	328·7	74·8	20·6	59·0	86·8	30·5
1901-02	295·3	82·2	32·4	64·4	88·9	40·2
1902-03	265·5	88·6	43·1	69·5	90·9	48·8
1903-04	239·2	94·0	52·7	74·2	92·6	56·1
1904-05	216·4	98·3	61·3	78·6	94·0	62·3
1905-06	197·1	101·7	68·9	82·6	95·2	67·2
1906-07	181·3	104·0	75·4	86·2	96·1	71·0
1907-08	169·0	105·3	80·9	89·5	96·7	73·5
1908-09	160·3	105·5	85·3	92·4	97·0	74·9
1909-10	155·0	104·7	88·7	95·0	97·1	75·1
1910-11	153·3	102·9	91·0	97·2	96·9	74·1
1911-12	155·1	100·1	92·3	99·0	96·4	71·8
1912-13	160·4	96·3	92·5	100·5	95·7	68·4
1913-14	169·2	91·4	91·7	101·6	94·7	63·8
1914-15	181·6	85·5	89·9	102·4	93·4	58·0
1915-16	197·4	78·6	86·9	102·8	91·8	51·0
1916·17	216·8	70·7	83·0	102·8	90·0	42·8
1917-18	239·7	61·7	78·0	102·5	87·9	33·4
1918-19	266·1	51·7	72·0	101·8	85·5	22·8
					Short term — B	
1919-20	1327·8	66·5	84·5	126·0	132·5	60·8
1920-21	1126·2	72·9	101·1	123·6	143·3	82·1
1921-22	968·0	78·7	115·3	121·1	154·8	105·7
1922-23	853·0	83·7	127·1	118·6	166·9	131·6
1923-24	781·4	88·0	136·6	116·2	179·6	159·8
1924-25	753·1	91·5	143·6	113·9	192·9	190·3
1925-26	768·1	94·3	148·3	111·7	206·8	223·1
1926-27	826·3	96·0	150·6	109·6	221·4	258·2
1927-28	927·9	97·6	150·5	107·5	236·6	295·6
1928-29	1072·8	98·2	148·0	105·5	252·4	335·3
1929-30	1261·0	98·0	143·2	103·6	268·8	377·3
1930-31	1492·5	97·1	135·9	101·8	285·9	421·6
1931-32	1767·3	95·4	126·3	100·1	—	468·2
1932-33	2085·4	93·0	114·2	98·5	—	517·0
1933-34	2446·8	89·8	99·8	96·9	—	568·2
1934-35	2851·5	85·9	83·0	95·4	—	621·7
1935-36	3299·5	81·3	63·8	94·1	—	677·5
1936-37	3790·9	75·9	42·3	92·8	—	735·5
1937-38	4325·5	69·8	18·3	91·5	—	795·9

IV — A, B.

trend values

Chemicals, drug and medicine	Dyes and colours	Machinery of all kinds	Metals and manufactures there of	Cotton, yarn and manufactures	Paper, paste-board and stationery	Electrical goods and apparatus
56·8	26·1	40·6	105·3	60·0	40·2	—
62·7	36·9	55·2	93·4	68·2	48·9	—
68·2	46·7	68·1	83·0	75·4	56·7	—
73·1	55·3	79·2	74·0	81·4	63·8	—
77·5	62·8	88·5	66·4	86·5	70·0	—
81·4	69·2	96·1	60·3	90·4	75·5	48·3
84·7	74·5	101·9	55·5	93·4	80·2	61·9
87·6	78·7	106·0	52·3	95·2	84·1	73·5
90·0	81·8	108·2	50·4	96·0	87·3	83·3
91·8	83·8	108·8	50·0	95·8	89·6	91·1
93·1	84·6	107·5	51·0	94·4	91·1	97·0
93·9	84·4	104·5	53·4	92·1	91·9	101·0
94·3	83·0	99·8	57·3	88·7	91·9	103·1
94·0	80·6	93·3	62·6	84·2	91·1	103·3
93·3	77·0	85·0	69·3	78·6	89·5	101·6
92·0	72·3	75·0	77·5	72·0	87·1	98·0
90·3	66·5	63·1	87·1	64·4	83·9	92·4
88·1	59·6	49·6	98·1	55·7	80·0	85·0
88·3	51·6	34·3	110·6	45·9	75·2	75·6
87·1	104·5	184·5	99·4	68·6	124·5	186·3
92·3	103·8	181·9	97·9	69·9	122·4	189·0
97·8	103·7	179·9	96·2	70·8	120·9	192·8
103·8	104·3	178·5	94·6	71·1	120·3	197·8
110·2	105·6	177·7	93·0	70·9	120·4	203·9
117·1	107·6	177·5	91·3	70·3	121·2	211·3
124·3	110·3	177·9	89·6	69·2	122·8	219·7
132·0	113·6	178·9	87·8	67·6	125·2	229·4
140·0	117·7	180·5	86·1	65·4	128·3	240·1
148·5	122·4	182·8	84·3	62·9	132·2	252·1
157·4	127·8	185·6	82·5	59·8	136·8	265·2
166·7	133·9	189·0	80·6	56·2	142·2	279·5
176·4	140·7	193·1	78·7	52·1	148·3	295·0
186·6	148·1	197·7	76·8	47·6	155·2	311·5
197·1	156·3	202·9	74·9	42·6	162·7	329·3
208·1	165·1	208·8	73·0	37·0	171·3	348·2
217·5	174·6	215·2	71·0	31·0	180·5	368·3
231·3	184·8	222·3	69·0	24·5	190·4	389·5
243·5	195·7	230·0	67·0	17·5	201·1	411·9

APPENDIX TABLE

Long term

Year	Grain, pulse and flour	Liquors	Sugar	Spices	Oils, vegetable, animal and mineral	Cotton, raw and waste
1900-01	572·64	92·87	25·67	72·33	109·60	120·54
1901-02	475·75	92·96	33·44	73·99	103·25	100·70
1902-03	388·70	93·02	40·78	75·72	97·74	82·93
1903-04	311·90	93·05	47·69	77·42	93·07	67·23
1904-05	244·12	93·05	54·17	79·09	89·24	53·60
1905-06	186·59	93·02	60·22	80·73	86·25	42·04
1906-07	138·90	92·96	65·84	82·34	84·10	32·55
1907-08	101·05	92·87	71·03	83·92	82·79	25·13
1908-09	73·04	92·75	75·79	85·47	82·32	19·78
1909-10	54·87	92·60	80·12	86·99	82·69	16·50
1910-11	46·54	92·42	84·02	88·48	83·90	15·29
1911-12	48·03	92·21	87·49	89·94	85·95	16·15
1912-13	59·36	91·97	90·53	91·37	88·84	19·08
1913-14	80·53	91·70	93·14	92·77	92·57	24·08
1914-15	111·62	91·37	95·32	94·14	97·14	31·15
1915-16	152·47	91·01	97·07	95·48	102·55	40·29
1916-17	203·16	90·62	98·39	96·79	108·80	51·50
1917-18	263·69	90·20	99·28	98·07	115·89	64·78
1918-19	334·06	89·75	99·74	99·32	123·82	80·13
1919-20	414·27	89·27	99·77	100·54	132·59	97·55
1920-21	504·32	88·76	99·37	101·73	142·20	117·04
1921-22	604·21	88·22	98·54	102·89	152·65	138·60
1922-23	713·94	87·65	97·28	104·02	163·94	162·23
1923-24	833·51	87·05	95·59	105·12	176·07	187·93
1924-25	962·92	86·42	93·47	106·19	189·04	215·70
1925-26	1102·17	85·76	90·92	107·23	202·85	245·54
1926-27	1251·26	85·07	87·94	108·24	217·50	277·45
1927-28	1410·19	84·35	84·53	109·22	232·99	311·43
1928-29	1578·96	83·60	80·69	110·17	249·32	347·48
1929-30	1757·57	82·82	76·42	111·09	266·49	385·60
1930-31	1946·02	82·01	71·72	111·98	284·50	425·77
1931-32	2144·31	81·17	66·59	112·84	—	468·05
1932-33	2352·44	80·30	61·03	113·67	—	512·38
1933-34	2570·41	79·40	55·04	114·47	—	558·78
1934-35	2798·22	78·47	48·62	115·24	—	607·25
1935-36	3035·87	77·51	41·77	115·98	—	657·79
1936-37	3283·36	76·52	34·49	116·69	—	710·40
1937-38	3540·69	75·50	26·78	117·37	—	765·08

IV (C)

trend values

Chemicals, drugs and medicine	Dyes and colours	Machinery of all kinds	Metals and manufactures there of	Cotton, yarn and manufactures	Paper, pasteboard and stationery	Electrical goods and apparatus
34·55	57·73	66·39	18·91	77·70	37·64	—
40·37	58·01	68·94	27·56	79·00	42·94	—
46·09	58·46	71·60	35·75	80·15	48·13	—
51·71	59·08	74·37	43·48	81·15	53·21	—
57·23	59·87	77·25	50·75	82·00	58·18	—
62·65	60·83	80·24	57·56	82·70	63·04	57·25
67·97	61·96	83·34	63·91	83·25	67·79	60·37
73·19	63·26	86·55	69·80	83·65	72·43	63·99
78·31	64·73	89·87	75·23	83·90	76·96	68·11
83·33	66·37	93·30	80·20	84·00	81·38	72·73
88·25	68·18	96·84	84·71	83·05	85·69	77·85
93·07	70·16	100·49	88·76	82·85	89·89	83·47
97·79	72·31	104·25	92·35	82·50	93·98	89·59
102·41	74·63	108·12	95·48	82·00	97·96	96·21
106·93	77·12	112·10	98·15	81·36	101·83	103·33
111·35	79·78	116·19	100·36	80·55	105·59	110·95
115·67	82·61	120·39	102·11	79·60	109·24	119·07
119·89	85·61	124·70	103·40	78·50	112·78	127·69
124·01	88·78	129·12	104·23	77·25	116·21	136·81
128·03	92·12	133·65	104·60	75·85	119·53	146·43
131·95	95·63	138·29	104·51	74·30	122·74	156·55
135·77	99·31	143·04	103·96	72·60	125·84	167·17
139·49	103·16	147·90	102·95	70·75	128·83	178·29
143·11	107·18	152·87	101·48	68·75	131·71	189·91
146·63	111·37	157·95	99·55	66·60	134·48	202·03
150·05	115·73	163·14	97·16	64·30	137·14	214·65
153·37	120·26	168·44	94·31	61·85	139·69	227·77
156·59	124·96	173·85	91·00	59·25	142·13	241·39
159·71	129·83	179·37	87·23	56·50	144·46	255·51
162·73	134·87	185·00	83·00	53·60	146·68	270·13
165·65	140·08	190·74	78·31	50·55	148·79	285·25
168·47	145·46	196·59	73·16	47·35	150·79	300·87
171·19	151·01	202·55	67·55	44·00	152·68	316·99
173·81	156·73	208·62	61·48	40·50	154·46	333·61
176·33	162·62	214·80	54·95	36·85	156·13	350·73
178·75	168·68	221·09	47·96	33·05	157·69	368·35
181·07	174·91	227·49	40·51	29·10	159·14	386·47
183·29	181·31	234·00	32·60	25·00	160·48	405·09

APPENDIX : TABLE

Short term

Year	Grain, pulse and flour	Liquors	Sugar	Spices	Oils, vegetable, animal and mineral	Cotton, raw and waste
						Short term — A
1900-01	103·10	0·45	75·06	14·33	3·60	200·06
1901-02	—34·41	—0·11	27·29	—4·95	23·59	—20·65
1902-03	—66·59	—1·81	—13·15	—3·02	7·81	—43·79
1903-04	—80·06	—2·96	—17·67	—10·27	—4·53	—86·81
1904-05	86·50	1·69	—22·54	0·80	—2·26	25·46
1905-06	7·83	7·61	—18·27	—2·26	—28·56	—2·54
1906-07	—1·21	1·37	0·80	2·25	—26·31	—33·49
1907-08	18·09	2·42	—5·27	—0·65	—7·64	—13·10
1908-09	306·48	—6·36	—3·03	—2·70	10·07	—32·04
1909-10	9·13	—7·10	—2·66	—0·37	—12·05	—49·25
1910-11	—50·30	—7·04	11·22	11·37	—9·49	—75·15
1911-12	—58·03	—4·12	—9·19	0·98	21·86	172·72
1912-13	—60·73	9·05	14·36	—1·67	9·43	227·26
1913-14	—25·25	15·95	33·91	—3·05	10·71	—62·86
1914-15	45·61	0·79	—16·20	3·55	25·63	—36·03
1915-16	97·64	—4·07	1·21	1·79	14·81	—77·84
1916-17	—60·01	—1·50	—10·49	—1·27	7·37	—66·12
1917-18	—87·48	—12·79	10·40	—11·02	—21·47	—37·13
1918-19	52·67	7·75	0·03	6·86	—22·91	67·46
						Short term — B
1919-20	—13·89	6·54	—21·87	—23·80	18·59	—55·73
1920-21	—98·61	23·11	—53·40	—35·21	—4·69	—7·77
1921-22	218·18	—10·54	—7·02	—31·25	—13·49	87·71
1922-23	—77·91	—14·10	—45·72	—18·38	—13·35	—33·89
1923-24	—74·24	—15·88	—52·26	—2·77	2·35	—35·17
1924-25	—93·60	—9·17	—30·45	—13·18	5·86	—13·77
1925-26	—66·49	—5·70	—25·84	1·17	5·97	—36·13
1926-27	—55·42	1·54	—16·07	—1·88	—9·76	43·60
1927-28	18·41	13·92	—25·12	—19·63	7·61	81·42
1928-29	375·94	8·08	—14·54	8·01	5·35	—29·88
1929-30	108·20	20·84	—3·25	23·31	2·97	—48·42
1930-31	26·93	15·60	1·11	2·22	—7·20	13·74
1931-32	—39·59	—10·36	—39·65	—2·01	—	37·50
1932-33	—74·80	—9·01	—51·85	—0·15	—	33·03
1933-34	—65·30	—15·50	—63·83	8·85	—	—38·74
1934-35	—0·44	—10·62	—63·14	22·16	—	—20·94
1935-36	—51·80	—1·58	—56·76	34·17	—	—8·36
1936-37	—81·98	4·34	—92·43	46·41	—	—28·20
1937-38	110·84	10·06	—89·24	38·98	—	—37·10

V—A, B,
fluctuations

Chemicals, drugs and medicine	Dyes and colours	Machinery of all kinds	Metals and manufactures there of	Cotton, yarn and manufactures	Paper, pasteboard and stationery	Electrical goods and apparatus
—11·79	45·52	11·71	—54·70	10·98	20·28	—
1·21	20·24	8·89	—45·73	7·61	9·27	—
5·92	8·87	—8·17	—28·67	0·59	6·32	—
3·00	8·70	—7·66	—7·68	—7·29	—4·03	—
—4·24	—14·50	—6·10	—0·76	1·31	—6·34	—
—8·81	—23·14	2·42	15·01	4·71	—10·01	6·54
—13·36	—34·78	3·83	30·00	—10·56	—13·74	37·49
—12·51	—38·51	2·79	61·12	—6·84	—11·21	—7·49
—10·30	0·85	14·19	69·42	—20·01	—11·07	—16·66
8·28	11·02	—5·86	78·46	—11·02	1·68	—22·62
3·40	18·73	—17·52	70·02	—6·72	0·50	—21·97
5·26	13·52	—25·96	66·75	2·09	0·43	—7·45
3·86	28·14	—3·80	71·37	25·67	16·45	9·87
14·30	29·57	45·28	118·67	44·24	29·46	42·39
9·38	18·31	27·90	23·35	17·14	8·75	16·65
11·71	—33·77	—7·80	—18·71	—11·83	—4·57	—4·13
—13·94	—19·89	—22·56	—56·83	—25·74	5·37	—15·27
—2·68	—17·01	—22·75	—69·83	—16·99	—14·95	—15·25
—10·66	4·98	13·58	—68·83	—2·15	—5·06	5·04
22·76	—8·72	—45·47	—10·19	0·97	—17·05	—27·12
4·50	6·20	—9·29	14·16	—2·92	60·69	26·57
—12·30	2·31	65·99	—3·89	—24·40	—28·80	48·02
—1·86	8·70	30·53	—3·28	5·07	—7·53	—13·09
5·20	13·52	13·18	—0·05	5·58	—6·44	—8·11
—13·81	—2·61	—20·84	—4·34	15·65	—11·71	—31·12
—16·50	—26·10	—18·89	—4·30	—3·57	—13·84	—22·26
—1·03	—10·77	—19·74	—2·18	5·85	—3·56	—9·79
1·13	6·99	—1·24	34·76	15·21	—0·29	2·15
1·07	12·41	19·27	40·63	26·02	15·17	16·23
7·31	—0·95	17·68	22·87	25·41	23·84	28·17
—2·40	—1·87	—2·18	—13·90	—38·61	—0·54	13·35
5·82	4·35	—14·17	—40·06	—41·31	—3·38	—9·67
—1·32	—8·26	—22·05	—50·29	—13·21	0·31	—13·39
2·93	—7·02	—1·20	—42·34	—30·20	—4·72	—12·32
7·12	9·62	0··1	—28·34	3·16	—1·40	5·98
9·50	11·04	5·04	38·85	19·60	2·78	9·89
—4·30	—4·18	4·59	14·90	25·20	—7·36	2·31
—9·68	—4·60	4·19	38·67	31·75	3·29	—6·41

APPENDIX TABLE

Long term Fluctuations

Year	Grain, pulse and flour	Liquors	Sugar	Spices	Oils, vegetable, animal and mineral	Cotton, raw and waste
1900-01	16·57	—19·13	40·63	—6·73	—18·07	—24·17
1901-02	—59·28	—11·68	23·21	—16·32	6·44	—68·32
1902-03	—77·18	—6·47	—8·29	—10·97	0·27	—66·96
1903-04	—84·69	—1·99	—9·00	—13·98	—5·02	10·07
1904-05	—88·03	7·47	—12·31	0·13	2·98	45·71
1905-06	13·89	17·61	—6·51	—0·04	—21·16	55·80
1906·07	28·94	13·38	15·43	7·36	—15·81	45·01
1907-08	97·52	16·05	7·84	5·93	7·86	154·28
1908·09	791·98	6·52	9·12	5·18	29·73	157·33
1909-10	208·36	5·08	7·71	8·75	3·28	130·91
1910-11	63·73	3·55	20·44	22·29	4·53	20·34
1911-12	35·54	4·11	—4·22	11·14	36·70	21·30
1912-13	6·13	14·17	16·87	8·13	17·85	17·35
1913-14	57·08	15·59	31·84	6·18	13·21	—1·58
1914-15	136·88	—5·69	—21·00	12·60	20·75	19·10
1915-16	155·92	—17·15	—9·34	8·99	2·78	—71·95
1916-17	—57·32	—23·20	—24·48	4·70	—11·21	—71·84
1917-18	—88·62	—40·35	—29·59	—7·01	—40·46	—66·58
1918-19	21·59	—37·94	—27·81	9·54	—46·78	—52·33
1919-20	176·00	—20·69	—33·85	—4·52	18·49	—72·42
1920-21	—96·91	1·17	—52·60	—21·26	—3·87	—35·32
1921-22	409·76	—20·20	8·79	—19·34	—12·28	43·15
1922-23	—73·61	—17·97	—29·07	—6·94	—11·80	—46·37
1923-24	—75·85	—14·99	—31·79	7·50	4·39	—44·87
1924-25	—94·99	—3·84	6·88	—6·86	8·02	—23·92
1925-26	—76·55	3·66	20·99	5·38	8·06	—41·96
1926-27	—70·56	14·96	43·73	—0·68	—8·14	33·65
1927-28	—22·09	31·83	33·32	—20·89	9·28	72·21
1928-29	223·36	26·91	56·77	3·46	6·65	—32·34
1029-30	49·37	42·91	81·24	15·04	3·86	—49·53
1930-31	—2·65	36·81	91·58	—7·04	—6·75	12·61
1931-32	—50·21	5·33	14·43	—13·06	—	37·53
1932-33	—77·66	5·35	—9·88	—13·52	—	34·24
1933-34	—66·97	—4·41	—34·42	—7·84	—	—37·70
1934-35	1·45	—2·13	—37·06	1·18	—	—19·06
1935-36	—46·83	3·21	—33·92	8·81	—	—5·62
1936-37	—79·19	3·50	—90·72	16·38	—	—25·75
1937·38	157·57	1·72	—92·64	8·38	—	42·62

V (C)

of Groups I, II, III

Chemicals, drugs and medicine	Dyes and colours	Machinery of all kinds	Metals and manufactures there of	Cotton, yarn and manufactures	Paper, paste-board and stationery	Electrical goods and apparatus
83·79	—34·26	—32·07	152·25	—14·29	28·59	—
57·30	—23·46	—12·82	83·96	—7·09	24·36	—
56·65	—13·10	—12·71	65·59	—5·43	25·29	—
45·81	1·73	—1·71	57·08	—6·96	15·02	—
29·65	—10·31	7·57	29·85	+6·83	12·75	—
18·44	—12·54	22·63	20·40	14·51	7·82	—10·04
7·40	—21·56	26·95	12·97	0·30	2·08	40·96
4·65	—23·49	26·82	20·63	6·04	3·13	5·80
3·05	27·44	37·53	13·52	—8·46	0·83	1·89
19·28	40·12	9·75	11·22	1·43	11·94	—3·07
9·12	47·38	—8·41	2·35	6·08	6·90	—2·76
6·26	36·55	—22·98	0·38	13·46	2·68	12·02
0·11	47·14	—7·91	6·33	35·03	13·85	26·47
4·99	39·89	25·32	43·38	48·05	20·36	52·89
—4.61	18·13	—3·03	—12·79	13·21	—4·45	14·68
—7·68	—39·96	—40·53	—37·23	—21·17	—21·30	—15·37
—32·83	—35·48	—59·38	—63·18	—39·95	—27·32	—34·24
—28·52	—42·19	—69·29	—71·37	—41·15	—39·71	—43·61
—38·55	—38·95	—69·87	—61·62	—41·88	—38·56	—41·96
—16·50	3·56	—24·73	—14·63	—8·64	—13·58	—7·26
—26·94	15·24	19·31	6·88	—8·61	60·18	52·79
—36·80	6·84	108·75	—11·02	—26·31	—31·58	70·72
—29·65	9·93	57·53	—11·12	5·58	—13·68	—3·58
—22·02	11·87	31·55	—8·45	8·95	—14·51	—1·32
—31·19	—5·90	—11·05	—12·31	22·07	—20·43	—27·98
—30·82	—29·58	—11·55	—11·79	3·73	—22·85	—20·43
—14·85	—15·68	—14·75	—8·92	15·60	—13·59	—9·16
—9·57	0·75	2·56	27·43	27·26	—10·01	1·62
—6·02	5·99	21·54	35·85	40·18	5·36	14·67
3·79	—6·13	18·05	22·05	39·83	15·48	25·83
—1·78	—6·20	—3·06	—11·38	—31·75	—4·97	11·06
10·82	0·92	—15·71	—35·48	—35·37	—4·97	—11·46
7·54	—10·01	—23·92	—43·45	—6·14	1·98	—14·89
16·74	—7·29	—3·89	—29·73	—26·67	0·48	—13·46
26·41	11·30	—2·79	—4·82	3·66	8·18	5·21
34·43	14·95	2·27	105·59	12·25	17·64	9·87
22·22	1·25	2·20	95·75	5·50	10·85	2·98
19·59	2·97	2·39	184·97	—7·60	29·42	—4·96

APPENDIX: TABLE VI

Periodogram Analysis Table.

Period	$A\mu$	$B\mu$	$S\mu^2 = A\mu^2 + B\mu^2$	$S\mu^{12} = \frac{n^1}{n}$ $S\mu^2$
$\mu = 2$	−0·68	0	·46	0·46
3	−2·17	0·67	5·16	4·89
4	−3·39	4·83	34·84	33·01
5	1·64	−1·97	6·55	6·04
6	−0·10	−0·82	0·68	0·64
7	10·58	9·61	204·17	188·05
8	−3·86	−5·94	50·12	42·20
9	−1·33	10·74	117·01	110·85
10	5·86	10·49	144·33	113·95
11	4·34	7·83	80·11	69·58
12	9·48	9·14	173·48	164·34
13	15·91	−0·48	253·46	173·42
14	13·26	−4·41	195·24	143·86
15	12·83	−7·97	228·01	180·01
16	4·98	−11·21	150·52	126·75
17	−0·81	−8·17	67·42	60·32
18	1·64	−5·10	28·72	27·21
19	0·25	−2·83	8·08	8·08

APPENDIX

(A) *Short term trends for* 1900-19

(1) Grain, Pulse and flour:

$$y = 207{\cdot}737 - 3{\cdot}475\xi_1 + 1{\cdot}757\xi_2 - 0{\cdot}255\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	4669881·541	18	259437·86	—	—
First order regression ..	6883·320	1	6883·32	39·86	246·5
Deviation from the straight line ..	4662998·221	17	274294·01	—	—
2. Second order regression ..	41878·240	1	41878·24	6·89	246·0
Deviation from the second degree curve ..	4621119·981	16	288819·999	—	—
3. Third order regression ..	19913·740	1	19913·74	15·41	245·5
Deviation from the third degree curve ..	4601206·241	15	306747·08	—	—

The third order regression is not significant.

(2) Liquors:

$$y = 89{\cdot}34 - 1{\cdot}28\xi_1 - 0{\cdot}513\xi_2 - 0{\cdot}003\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	5128·26	18	284·90	—	—
First order regression ..	929·50	1	929·50	3·76	4·45
Deviation from the straight line ..	4198·76	17	246·99	—	—
2. Second order regression ..	3567·86	1	3567·86	90·48	4·49
Deviation from the second degree curve ..	630·91	16	39·43	—	—
3. Third order regression ..	2·36	1	2·36	17·993	245·5
Deviation from the third degree curve ..	628·555	15	41·91	—	—

The third order regression is not significant. So the trend curve can be taken as $y = 89{\cdot}34 - 1{\cdot}28\xi_1 - {\cdot}513\xi_2$ for the term in ξ_3 is dropped.

(3) Sugar :

$$y = 72{\cdot}98 + 2{\cdot}85\xi_1 - 0{\cdot}523\xi_2 - 0{\cdot}051\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	8985·88	18	499·22	—	—
First order regression ..	4636·38	1	4636·38	18·12	4·45
Deviation from the straight line ..	4349·50	17	255·82	—	—
2. Second order regression ..	3710·30	1	3710·30	92·91	4·49
Deviation from the second degree curve ..	639·20	16	39·94	—	—
3. Third order regression ..	809·28	1	809·28	93·44	4·54
Deviation from the third degree curve ..	129·92	15	8·66	—	—

The third order regression is significant. So the above third degree curve is a good fit.

(4) Spices :

$$y = 89{\cdot}58 + 2{\cdot}38\xi_1 - 0{\cdot}179\xi_2 - 0{\cdot}008\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	3944·54	18	219·14	—	—
First order regression ..	3220·50	1	3220·50	75·62	4·45
Deviation from the straight line ..	724·04	17	42·59	—	—
2. Second order regression ..	431·10	1	431·10	23·96	4·49
Deviation from the second degree curve ..	289·94	16	18·12	—	—
3. Third order regression ..	18·30	1	18·30	1·01	4·54
Deviation from the third degree curve ..	271·64	15	18·11	—	—

The third order regression is not significant and the trend curve can be taken as $y = 89{\cdot}58 + 2{\cdot}38\xi_1 - 0{\cdot}179\xi_2$.

(5) Oils — vegetable, animal and mineral :

$$y = 93{\cdot}01 - 0{\cdot}065\xi_1 - 0{\cdot}136\xi_2 - 0{\cdot}086\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	4693·366	18	260·742	—	—
First order regression ..	2·308	1	2·308	115·55	246·5
Deviation from the straight line ..	4691·058	17	275·939	—	—
2. Second order regression ..	250·971	1	250·971	1·106	246·0
Deviation from the second degree curve ..	4440·087	16	277·500	—	—
3. Third order regression ..	2286·995	1	2286·995	15·97	4·54
Deviation from the third degree curve ..	2153·092	15	143·534	—	—

The third degree curve is a good fit.

(6) Cotton, raw and waste :

$$y = 57{\cdot}15 - 0{\cdot}42\xi_1 - 0{\cdot}598\xi_2 - 0{\cdot}120\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	61893·47	18	—	—	—
First order regression ..	101·97	1	101·97	35·64	246·5
Deviation from the straight line ..	61791·50	17	3634·79	—	—
2. Second order regression ..	4856·63	1	4856·63	1·36	4·49
Deviation from the second degree curve ..	56934·87	16	3558·43	—	—
3. Third order regression ..	4420·50	1	4420·50	1·28	4·54
Deviation from the third degree curve ..	52514·37	15	3445·28	—	—

(7) Chemicals, drugs and medicine :

$$y = 84{\cdot}09 + 1{\cdot}583\xi_1 - 0{\cdot}256\xi_2 - 0{\cdot}045\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	3567·38	18	198·18	—	—
First order regression ..	1428·42	1	1428·42	11·35	4·45
Deviation from the straight line ..	2138·96	17	125·82	—	—
2. Second order regression ..	888·57	1	888·57	11·37	4·49
Deviation from the second degree curve ..	1250·39	16	78·15	—	—
3. Third order regression ..	626·24	1	626·24	15·05	4·54
Deviation from the third degree curve ..	624·13	15	41·61	—	—

The third order regression is definitely significant. The above e.g. in third degree can be taken as a good fit.

(8) Dyes and colours :

$$y = 69{\cdot}14 + 1{\cdot}42\xi_1 - 0{\cdot}554\xi_2 - 0{\cdot}069\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	10150·71	18	—	—	—
First order regression ..	1146·27	1	1146·27	2·16	4·45
Deviation from the straight line ..	9004·44	17	529·67	—	—
2. Second order regression ..	4164·76	1	4164·76	13·77	4·49
Deviation from the second degree curve ..	4839·68	16	302·48	—	—
3. Third order regression ..	1039·73	1	1439·73	4·105	4·59
Deviation from the third degree curve ..	3799·95	15	253·33	—	—

The third order regression is not significant. The second degree curve is a good fit.

(9) Machinery of all kinds:

$$y = 82{\cdot}34 - 0{\cdot}351\xi_1 - 0{\cdot}881\xi_2 - 0{\cdot}018\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	14872·24	18	826·24	—	—
First order regression ..	70·11	1	70·11	12·42	246·5
Deviation from the straight line ..	14802·13	17	870·71	—	—
2. Second order regression ..	10527·22	1	10527·22	39·40	4·49
Deviation from the second degree curve ..	4274·91	16	267·18	—	—
3. Third order regression ..	100·57	1	100·57	2·767	245·5
Deviation from the third degree curve ..	4174·34	15	278·29	—	—

The third order regression is not significant. The second degree curve is a good fit.

(10) Metals and manufactures there of:

$$y = 71{\cdot}52 + 0{\cdot}286\xi_1 + 0{\cdot}716\xi_2 - 0{\cdot}053\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	10947·47	18	608·19	—	—
First order regression ..	46·49	1	46·49	13·79	246·5
Deviation from the straight line ..	10900·92	17	641·23	—	—
2. Second order regression ..	6959·36	1	6959·36	28·25	4·49
Deviation from the second degree curve ..	3941·56	16	246·35	—	—
3. Third order regression ..	862·61	1	862·62	4·28	4·54
Deviation from the third degree curve ..	3078·95	15	205·63	—	—

The second order regression is significant and absorbs a large part of the variance. The trend curve can be taken as

$$y = 71{\cdot}52 + 0{\cdot}286\xi_1 + 0{\cdot}716\xi_2$$

(11) Cotton yarn and manufactures:

$$y = 79{\cdot}85 - 0{\cdot}783\xi_1 - 0{\cdot}529\xi_2 - 0{\cdot}048\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	7453·06	18	—	—	—
First order regression ..	349·41	1	349·41	1·196	246·5
Deviation from the straight line ..	7103·65	17	417·86	—	—
2. Second order regression ..	3795·77	1	3795·77	18·36	4·49
Deviation from the second degree curve ..	3307·88	16	206·74	—	—
3. Third order regression ..	699·91	1	699·91	4·026	4·54
Deviation from the third degree curve ..	2607·97	15	173·87	—	—

The second degree curve is a good fit and the trend curve can be taken as $y = 79{\cdot}85 - 0{\cdot}783\xi_1 - 0{\cdot}529\xi_2$ dropping ξ_3

(12) Paper, paste-board and Stationery:

$$y = 77{\cdot}76 + 1{\cdot}95\xi_1 - 0{\cdot}394\xi_2 - 0{\cdot}052\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	5956·59	18	330·81	—	—
First order regression ..	2160·87	1	2160·87	9·68	4·45
Deviation from the straight line ..	3795·72	17	223·28	—	—
2. Second order regression ..	2102·73	1	2102·73	19·87	4·49
Deviation from the second degree curve ..	1692·99	16	105·81	—	—
3. Third order regression ..	816·57	1	816·57	13·98	4·54
Deviation from the third degree curve ..	876·42	15	58·43	—	—

The third degree curve (given above) is a good fit

(13) Electrical goods and apparatus:

$$(n = 14)$$

$$y = 86{\cdot}77 + 2{\cdot}10\xi^1{}_1 - 0{\cdot}955\ (\xi_1{}^2 - 21{\cdot}26) - 0{\cdot}154\ (\xi_1{}^3 - 38{\cdot}05)$$

where $\xi_1{}^1 = (t - 9{\cdot}2)$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	8081·40	13	—	—	—
First order regression ..	999·41	1	999·41	1·69	4·75
Deviation from the straight line ..	7081·99	12	590·17	—	—
2. Second order regression ..	2655·74	1	2655·74	6·6	4·84
Deviation from the second degree curve ..	4426·25	11	402·39	—	—
3. (Third order regression, Deviation from the third degree curve) ..	(The third order regression is not seen to be significant)				

The second degree curve is a good fit to this commodity.

(B) *Short term trends for* 1919-38

(1) Grain, pulse and flour:

$$y = 1722{\cdot}36 + 166{\cdot}54\xi_1 + 21{\cdot}65\xi_2 + 4{\cdot}15\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	88905384·63	18	—	—	—
First order regression ..	15809086·23	1	15809086·23	3·677	4·45
Deviation from the straight line ..	73096298·40	17	4299782·26	—	—
2. Second order regression ..	6360446·23	1	6360446·23	1·524	4·49
Deviation from the second degree curve ..	66735852·17	16	4170990·76	—	—
3. Third order regression ..	5294470·26	1	5294470·26	1·002	4·54
Deviation from the third degree curve ..	61441381·91	15	4096092·13	—	—

The third order regression is not significant.

(2) Liquors:

$$y = 87{\cdot}02 + 0{\cdot}19\xi_1 - 0{\cdot}371\xi_2 - 0{\cdot}007\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	4099·07	18	227·73	—	—
First order regression ..	20·12	1	20·12	11·93	246·5
Deviation from the straight line ..	4078·95	17	239·94	—	—
2. Second order regression ..	1866·68	1	1866·68	13·50	4·49
Deviation from the second degree curve ..	2212·27	16	138·27	—	—
3. Third order regression ..	13·99	1	13·99	10·48	245·5
Deviation from the third degree curve ..	2198·29	15	146·55	—	—

The third order regression is not significant. The second degree curve is a good fit to this commodity.

(3) Sugar :

$$y = 112{\cdot}212 - 3{\cdot}67\xi_1 - 1{\cdot}193\xi_2 + 0{\cdot}002\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	35131·85	18	1951·77	—	—
First order regression ..	7689·87	1	7689·87	4·76	4·45
Deviation from the straight line ..	27441·98	17	1614·23	—	—
2. Second order regression ..	19440·08	1	19440·08	38·87	4·49
Deviation from the second degree curve ..	8001·90	16	500·12	—	—
3. Third order regression ..	1·41	1	1·41	379·35	245·5
Deviation from the third degree curve ..	8000·49	15	533·37	—	—

The third degree curve is a good fit.

(4) Spices :

$$y = 106{\cdot}75 - 1{\cdot}93\xi_1 + 0{\cdot}413\xi_2 + 0{\cdot}003\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. Total ..	4448·90	18	247·16	—	—
First order regression ..	2114·13	1	2114·13	15·34	4·45
Deviation from the straight line ..	2334·77	17	137·34	—	—
2. Second order regression ..	2314·36	1	2314·36	1813·7	4·49
3. Deviation from the second degree curve ..	20·42	16	1·28	—	—

The second order regression is definitely significant. So the second degree is a good fit. The equation can be taken as

$$y = 106{\cdot}75 - 1{\cdot}93\xi_1 + 0{\cdot}413\xi_2$$

(5) Oils — vegetable, animal and mineral: 1919-31 ($n = 12$)

$$y = 203{\cdot}49 + 13{\cdot}94\xi_1{}^1 + {\cdot}310\ (\xi_1{}^1 - 11{\cdot}91) - 36\ (\xi_1{}^3 - 21{\cdot}25) \text{ where } \xi_1{}^1 = (t - 1925)$$

		Sums of squares	D. F.	Variance	F.	5% value
1. Total	..	31277·69	11	—	—	—
First order regression	..	27804·21	1	27804·21	82·93	4·96
Deviation from the straight line	..	3473·48	10	347·348	—	—
2. Second order regression	..	128·13	1	128·13	2·93	241·0
3. Deviation from the second degree curve	..	3345·35	9	371·91	—	—

The first line is a good fit to this commodity. $y = 203{\cdot}49 + 13{\cdot}90\ (\xi_1{}^1 - 11{\cdot}91)$

(6) Cotton, raw and waste:

$$y = 369{\cdot}74 + 40{\cdot}84\xi_1 + 1{\cdot}15\xi_2 + 0{\cdot}214\xi_3$$

		Sums of squares	D. F.	Variance	F.	5% value
1. Total	..	1366672·36	18	—	—	—
First order regression	..	950846·07	1	950846·07	38·87	4·45
Deviation from the straight line	..	415826·29	17	24460·37	—	—
2. Second order regression	..	97879·99	1	97879·99	5·09	4·49
Deviation from the second degree curve	..	307946·30	16	19246·64	—	—
3. Third order regression	..	14059·65	1	14059·65	1·39	245·5
Deviation from the third degree curve	..	293886·65	15	19592·44	—	—

The second degree curve is a good fit.

(7) Chemicals, drugs and medicine:

$$y = 154{\cdot}7 + 8{\cdot}69\xi_1 + 0{\cdot}207\xi_2 - 0{\cdot}071\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	46477·66	18	2582·09	—	—
First order regression ..	43044·88	1	43044·18	213·10	4·45
Deviation from the first line ..	3433·48	17	201·99	—	—
2. Second order regression ..	580·63	1	580·63	3·26	4·49
Deviation from the second degree curve ..	2852·85	16	178·30	—	—
3. Third order regression ..	1544·11	1	1544·11	17·0	4·54
Deviation from the third degree curve ..	1308·74	15	87·25	—	—

The third order regression is definitely significant. So the third degree curve is a good fit.

(8) Dyes and colours:

$$y = 132{\cdot}68 + 5{\cdot}06\xi_1 + 0{\cdot}342\xi_2 + 0{\cdot}383\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	18958·31	18	—	—	—
First order regression ..	14611·38	1	14611·38	56·81	4·45
Deviation from the first line ..	4346·93	17	256·88	—	—
2. Second order regression ..	1587·22	1	1587·22	7·21	4·49
Deviation from the second degree curve ..	2759·71	16	172·48	—	—

The second degree curve is a good fit. The equation of the trend curve can be taken as

$$y = 132{\cdot}68 + 5{\cdot}06\xi_1 + 0{\cdot}342\xi_2 \text{ dropping } \xi_3$$

(9) Machinery of all kinds:

$$y = 191{\cdot}82 + 2{\cdot}526\xi_1 + 0{\cdot}302\xi_2 + 0{\cdot}109\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	42097·652	18	—	—	—
First order regression ..	3636·942	1	3636·942	1·5007	4·45
Deviation from the straight line ..	38460·710	17	2262·390	—	—
2. Second order regression ..	9237·219	1	9237·219	5·05	4·49
Deviation from the second degree curve ..	29223·501	16	1826·469	—	—
3. Third order regression ..	3653·052	1	3653·052	2·14	4·54
Deviation from the third degree curve ..	25570·449	15	1704·697	—	—

The second degree curve is a good fit.

(10) Metals and manufactures there of:

$$y = 83{\cdot}88 - 1{\cdot}802\xi_1 - 0{\cdot}013\xi_2 + 0{\cdot}06\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	10182·89	18	565·72	—	—
First order regression ..	1853·07	1	1853·07	3·782	4·45
Deviation from the straight line ..	8329·82	17	489·19	—	—
2. Second order regression ..	2·25	1	2·25	231·12	246·0
Deviation from the second degree curve ..	8327·57	16	520·47	—	—
3. Third order regression ..	1111·27	1	1111·27	2·31	4·54
Deviation from the third degree curve ..	7216·30	15	481·09	—	—

The second degree curve is a good fit.

(11) Cotton yarn and manufactures :

$$y = 55{\cdot}50 - 2{\cdot}835\xi_1 - 0{\cdot}244\xi_2 + 0{\cdot}037\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. **Total** ..	7706·44	18	428·14	—	—
First order regression ..	4581·09	1	4581·09	24·92	4·45
Deviation from the straight line ..	3125·35	17	183·84	—	—
2. Second order regression ..	807·18	1	807·18	5·57	4·49
Deviation from the second degree curve ..	2318·17	16	144·89	—	—
3. Third order regression ..	408·28	1	408·28	3·21	4·54
Deviation from the third degree curve ..	1909·89	15	127·33	—	—

The second order regression is significant. So the second degree curve is a good fit.

(12) Paper, paste-board and stationery :

$$y = 143{\cdot}52 + 4{\cdot}25\xi_1 + 0{\cdot}38\xi_2 - 0{\cdot}47\xi_3$$

	Sums of squares	D. F.	Variance	F.	5% value
1. **Total** ..	21896·427	18	—	—	—
First order regression ..	10300·470	1	10300·470	15·10	4·45
Deviation from the straight line ..	11595·957	17	682·115	—	—
2. Second order regression ..	1953·504	1	1953·504	3·242	4·49
Deviation from the second degree curve ..	9642·453	16	602·653	—	—

The straight line is seen to be a good fit.

(13) Electrical goods and apparatus:

$$y = 269{\cdot}5 + 12{\cdot}534\xi_1 + 0{\cdot}580\xi_2 - 0{\cdot}043\xi_3$$

	Sums of squares	D.F.	Variance	F.	5% value
1. Total ..	131335·18	18	—	—	—
First order regression ..	89547·57	1	89547·57	36·43	4·45
Deviation from the straight line ..	41787·61	17	2458·09	—	—
2. Second order regression ..	4558·18	1	4558·18	4·67	4·49
Deviation from the second degree curve ..	37227·43	16	976·73	—	—
3. Third order regression ..	558·70	1	558·70	4·375	245·5
Deviation from the third degree curve ..	36670·73	15	2444·72	—	—

The second order regression is significant. The second degree curve is a good fit to this commodity.

G. S. PRESS, MADRAS

Fig. I

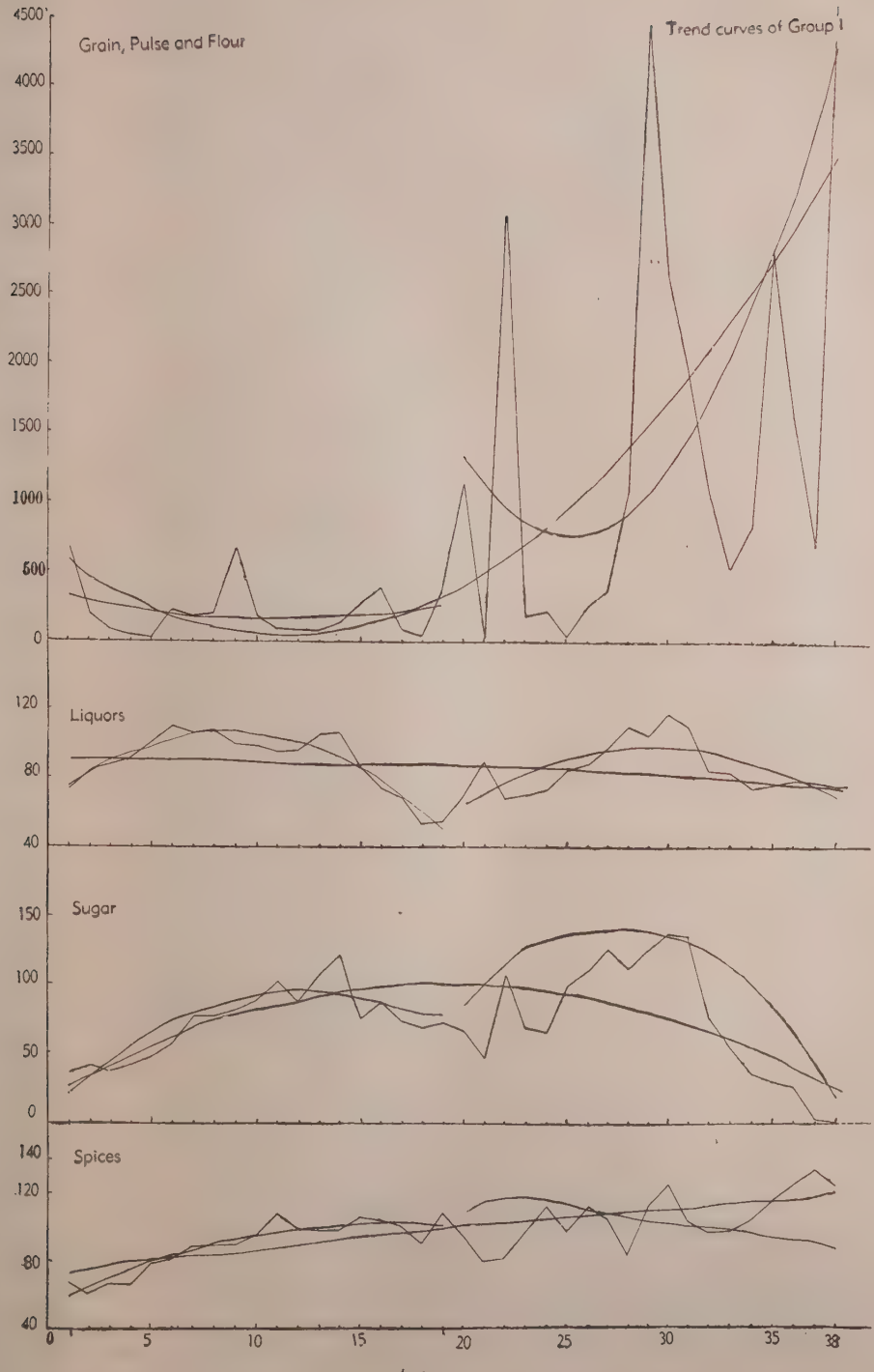

Grain, Pulse and Flour
Trend curves of Group I
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Liquors
120
80
40
Sugar
150
100
50
0
Spices
140
120
80
40
0
5
10
15
20
25
30
35
38
t →

Fig. II

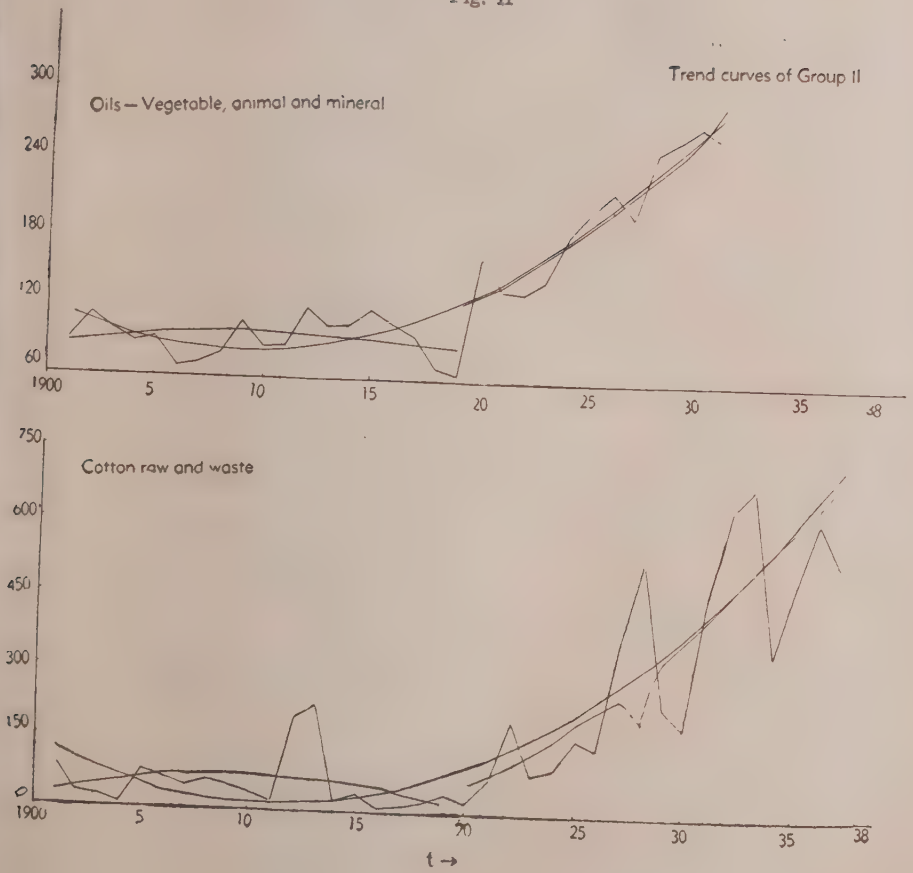

Trend curves of Group II
Oils — Vegetable, animal and mineral
300
240
180
120
60
1900
5
10
15
20
25
30
35
38
750
600
450
300
150
0
Cotton raw and waste
t →

Fig. III

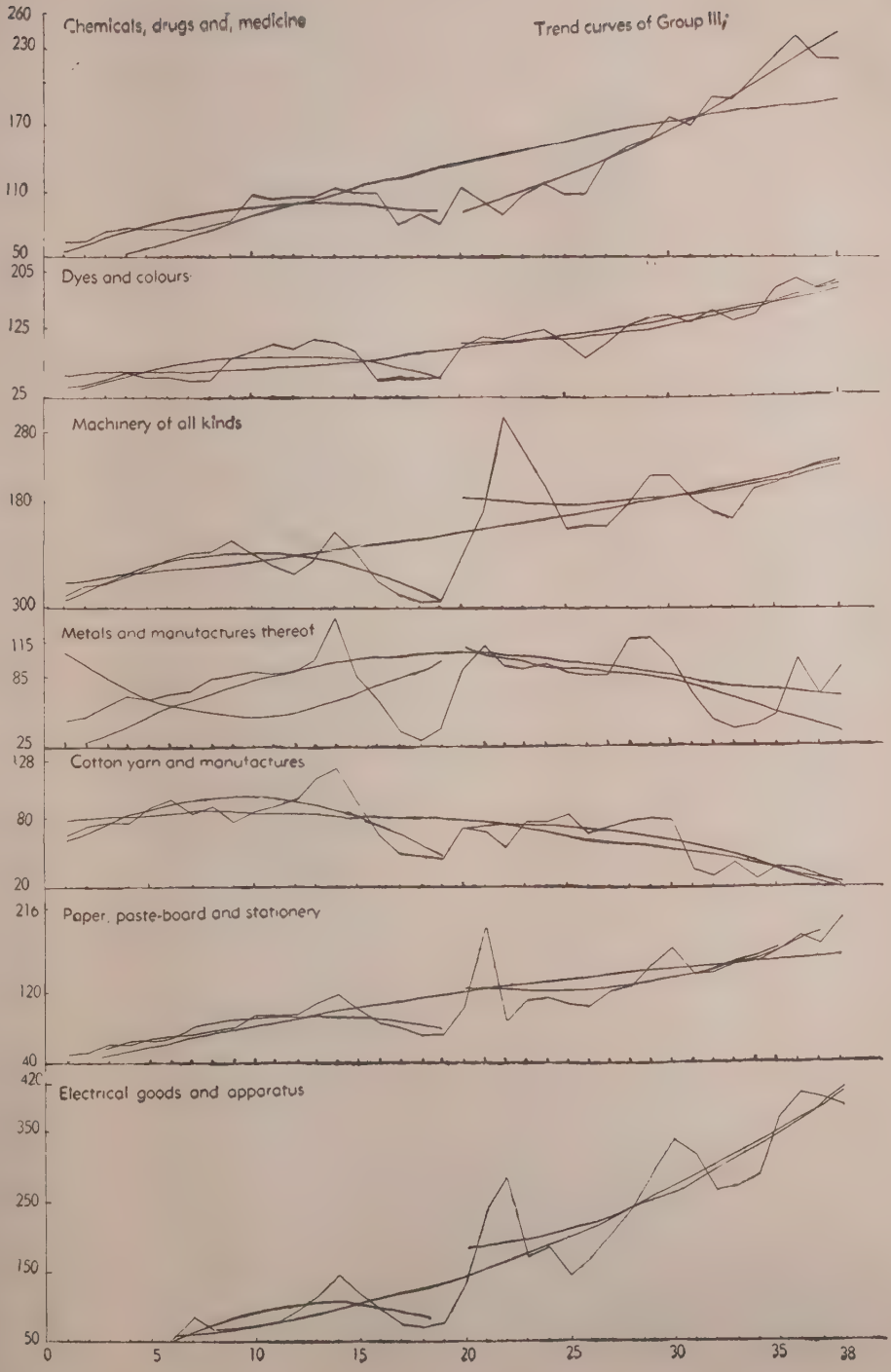

Chemicals, drugs and medicine
Trend curves of Group III
260
230
170
110
50
Dyes and colours
205
125
25
Machinery of all kinds
280
180
300
Metals and manufactures thereof
115
85
25
Cotton yarn and manufactures
128
80
20
Paper, paste-board and stationery
216
120
40
Electrical goods and apparatus
420
350
250
150
50
0
5
10
15
20
25
30
35
38
t →

Fig. IV

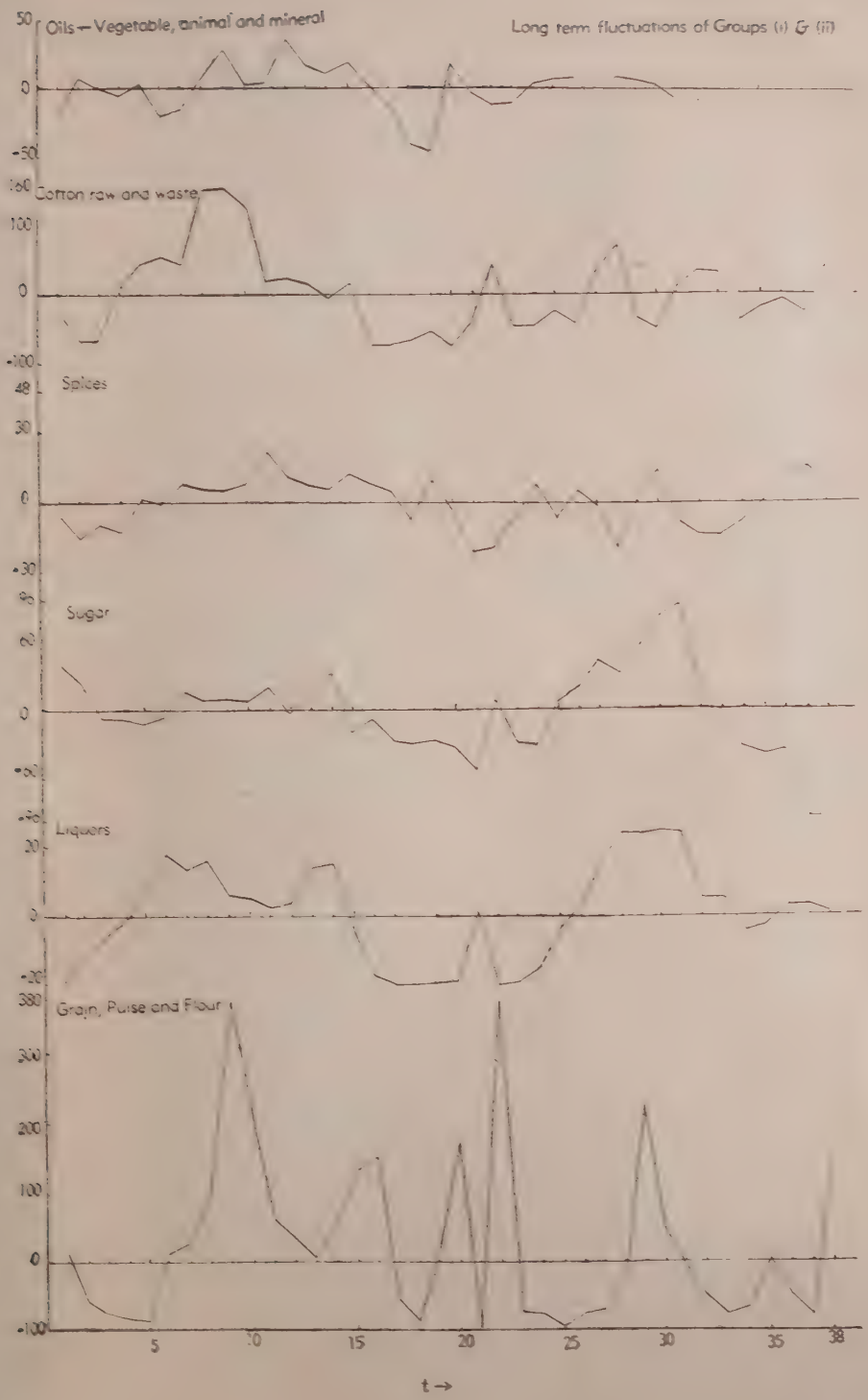

Oils — Vegetable, animal and mineral
Long term fluctuations of Groups (i) & (ii)
50
0
-50
Cotton raw and waste
100
0
-100
Spices
30
0
-30
Sugar
60
0
Liquors
20
0
-20
Grain, Pulse and Flour
300
200
100
0
-100
5
10
15
20
25
30
35
38
t →

Fig. V

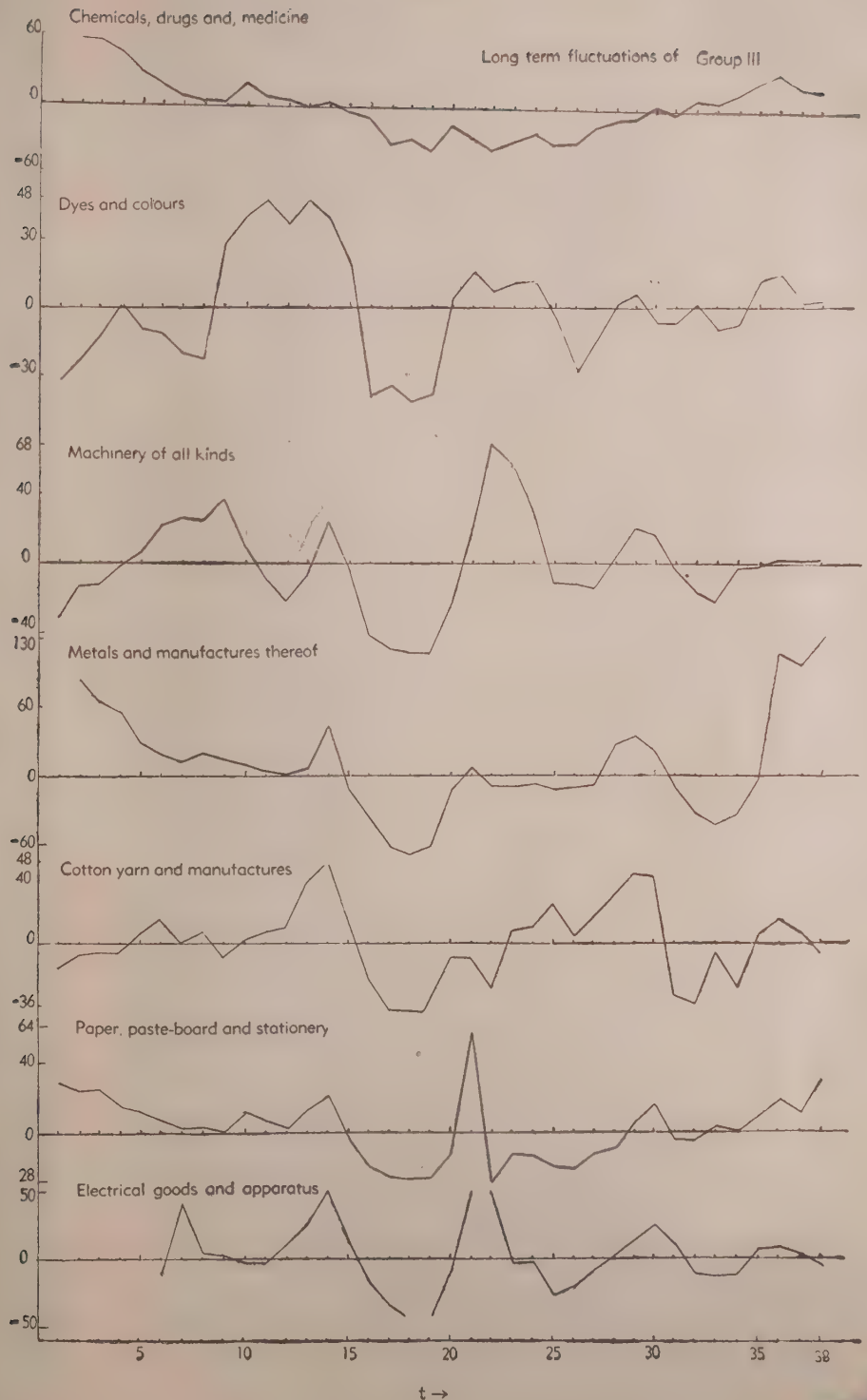
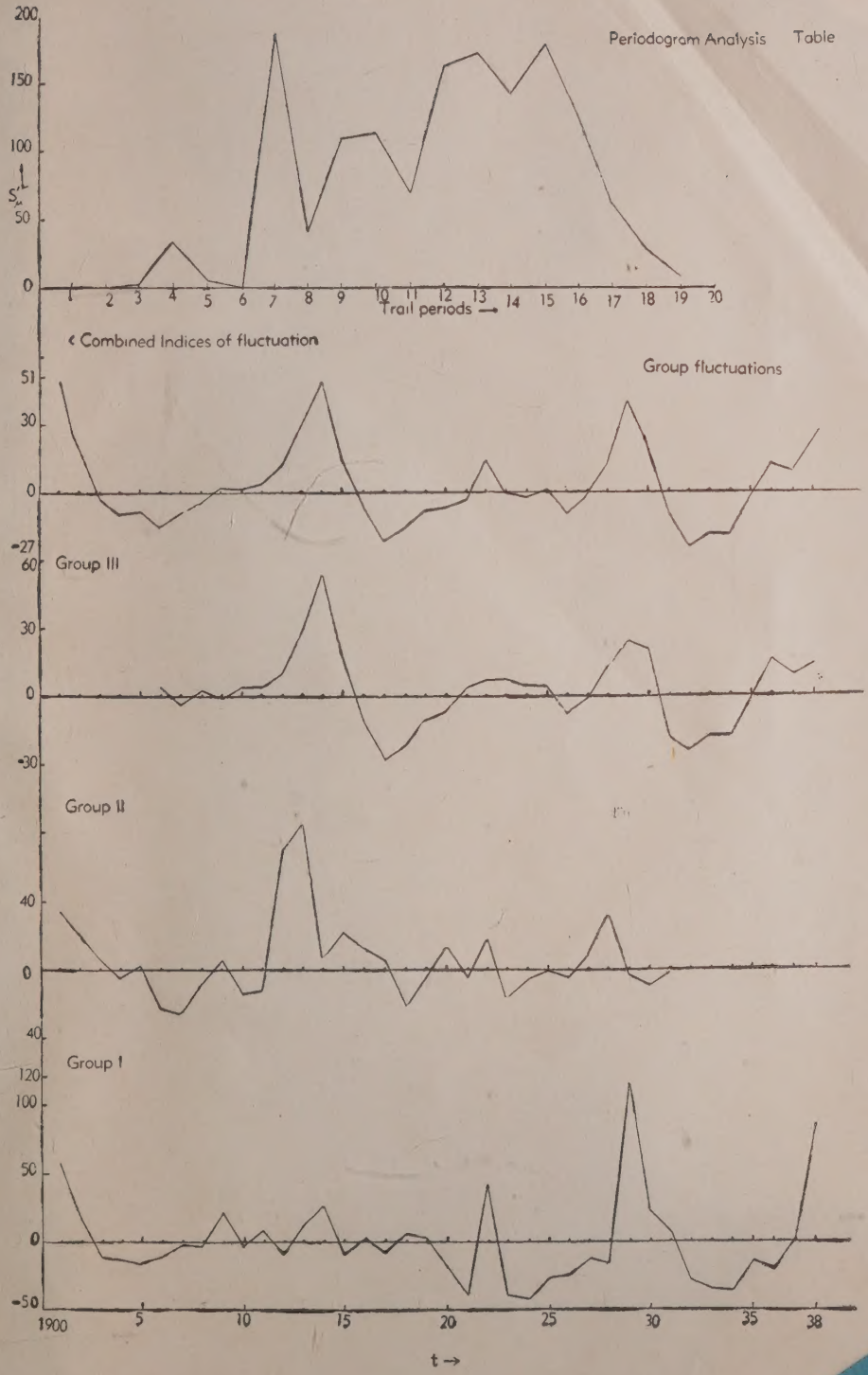

Chemicals, drugs and, medicine
Long term fluctuations of Group III
60
0
-60
Dyes and colours
48
30
0
-30
Machinery of all kinds
68
40
0
-40
Metals and manufactures thereof
130
60
0
-60
Cotton yarn and manufactures
48
40
0
-36
Paper, paste-board and stationery
64
40
0
28
Electrical goods and apparatus
50
0
-50
5
10
15
20
25
30
35
38
t →

Fig. VI


Periodogram Analysis Table
200
150
100
50
0
I
S
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Trail periods →
Combined Indices of fluctuation
Group fluctuations
51
30
0
-27
Group III
60
30
0
-30
Group II
40
0
40
Group I
120
100
50
0
-50
1900 5 10 15 20 25 30 35 38
t →

PUBLICATIONS

OF

THE INTER-UNIVERSITY BOARD, INDIA

		Price Rs. A. P.
1.	**Handbook of Indian Universities** ..	3 0 0 *or* 5*s*
2.	**Facilities for Oriental Studies and Research at Indian Universities** ..	0 8 0
3.	**Facilities for Scientific Research at Indian Universities** ..	0 12 0
4.	**Bulletin of the Inter-University Board, India**, Nos. 1 to 13 ..	1 0 0 *each*
5.	**Biological Outlook on Life and its Problems.** By J. ARTHUR THOMSON, M.A., LL.D., Regius Professor of Natural History, University of Aberdeen ..	0 2 0
6.	**Second, Third and Fourth Conference of Indian Universities** ..	1 0 0 *each*
7.	**Training of Teachers in Indian Universities** ..	0 8 0
8.	**Bibliography of Doctorate Theses in Science and Arts (Accepted by Indian Universities from January 1930 and from 1934)** ..	0 8 0 *each*
9.	**Annual Report of the Inter-University Board for 1940-41** ..	1 0 0

[POSTAGE AND V. P. CHARGES EXTRA]

Available from :

BANGALORE PRESS,
"LAKE VIEW", MYSORE ROAD,
BANGALORE CITY.